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UTILIZATION OF NAVY-GENERATED WASTE OILS AS BOILER FUEL 1/1
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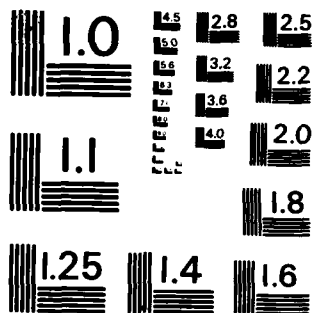
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FIELD SURVEY RESULTS

AUTHOR: T. T. Fu, PhD
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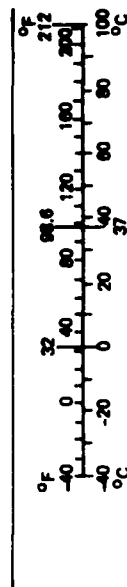
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
in ft yd mi	inches	2.5 30 0.9 1.6	centimeters	cm
	feet		centimeters	cm
	yards		meters	m
	miles		kilometers	km
in ² ft ² yd ² mi ²	square inches	6.5 0.09 0.8 2.6	square centimeters	cm ²
	square feet		square meters	m ²
	square yards		square meters	m ²
	square miles		square kilometers	km ²
oz lb	ounces	28 0.45 0.9	grams	g
	pounds		kilograms	kg
	short tons		tonnes	t
	(2,000 lb)			
tsp Tbsp fl oz c pt qt gal ft ³ yd ³	teaspoons	5 15 30 0.24 0.47 0.95 3.8 0.03 0.76	milliliters	ml
	tablespoons		milliliters	ml
	fluid ounces		milliliters	ml
	cups		liters	l
	pints		liters	l
	quarts		liters	l
	gallons		liters	l
	cubic feet		cubic meters	m ³
	cubic yards		cubic meters	m ³
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.35, SD Catalog No. C13.10.286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
mm cm m km	millimeters	0.04 0.4 3.3 1.1	inches	in
	centimeters		inches	in
	meters		feet	ft
	kilometers		yards	yd
cm ² m ² km ² ha	square centimeters	0.16 1.2 0.4 2.5	square inches	in ²
	square meters		square yards	yd ²
	square kilometers		square miles	mi ²
	hectares (10,000 m ²)		acres	
g kg t	grams	0.035 2.2 1.1	ounces	oz
	kilograms		pounds	lb
	tonnes (1,000 kg)		short tons	
ml l l l m ³ m ³	milliliters	0.03 2.1 1.06 0.26 36 1.3	fluid ounces	fl oz
	liters		pints	pt
	liters		quarts	qt
	liters		gallons	gal
	cubic meters		cubic feet	ft ³
	cubic meters		cubic yards	yd ³
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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pre-burning treatment, burning methods, equipment modifications, and operational requirements are discussed. Part 4 consists of: a comprehensive survey of the potential for utilizing waste oil by Navy/Marine Corps activities and a compilation of the reported experience of waste oil users.

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UTILIZATION OF NAVY-GENERATED WASTE OILS AS BOILER
FUEL - HANDBOOK OF GUIDELINES AND FIELD SURVEY RESULTS
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This technical note provides information for a variety of users at different levels of management and operation. Part 1 contains background information on waste oil generation and a survey of waste oil disposition. Part 2 provides pertinent information to Public Works Officers and planners. Topics include: source of waste oil, a survey of disposition of waste oil, restrictions on use as fuel, boiler fuels, air quality considerations, and economics. Part 3 provides procedural information to operators using waste oil as boiler fuel. Waste oil handling, pre-burning treatment, burning methods, equipment modifications, and operational requirements are discussed. Part 4 consists of: a comprehensive survey of the potential for utilizing waste oil by Navy/Marine Corps activities and a compilation of the reported experience of waste oil users.

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- Light waste oils - oils recovered from ship bilge and ballast water and contaminated high flashpoint fuels, representing an estimated 87% of the total waste oils generated throughout the Navy.
- Heavy waste oils - turbine engine drainings, shop facility wastes, and tank cleanings, estimated to be 9% of the total waste oils generated.
- Low flashpoint materials - used solvents and contaminated low flashpoint fuels, estimated at 4% of the total waste oils generated.

It should be noted that percentages are Navywide estimates only, and may vary considerably for specific sites.

Light and heavy waste oils are safe and suitable for boiler fuels. Low flashpoint materials are undesirable as boiler fuel for safety and environmental reasons. Of all the waste oil the Navy generates, more than 96% is therefore considered to be a desirable source of energy. Waste oil that can be utilized is of higher quality than the No. 6 fuel oil frequently used in boilers. In addition, this waste oil can be burned with no added adverse environmental effects.

Generation and Disposition of Waste Oil

Over a 2-year period (1980-82) NCEL has conducted a survey of waste oil generation and disposition by Navy and Marine Corps shore activities. Based on the Defense Energy Information System FY80 DEIS II report only 325 of the 592 Navy and Marine Corps activities with assigned Unit Identification Code (UIC) numbers showed fuel oil consumptions. Since these 325 activities have oil burning capability, they are considered potential candidates for burning waste oil and were therefore contacted during this survey. Results show approximately 19 million gal/yr of waste oil are generated by these 325 activities.

Of these 19 million gallons, only 57% was burned as a boiler fuel. The 43% not burned was disposed of in several ways: (1) local fire-fighting training, (2) NAVSUP, DLA, or DPDO resale, (3) weed/dust control, (4) sold or given to haulers, (5) paid to have hauled away, or (6) stored, no disposition planned.

The above figures and the earlier Navywide estimate of 26 million gal/yr (see Background), show that: (1) a large sum of waste oil is also generated by those activities having no fuel oil burning capabilities and (2) approximately 8 million gallons of waste oil generated Navywide were disposed of by nonburning methods. This illustrates the potential for more productive use of significant quantities of waste oil.

PART 2. PLANNING WASTE OIL UTILIZATION

This part discusses the planning factors that should be considered and evaluated for waste oil utilization. The sources generating waste oil are discussed, and oil products most likely to be found in the waste oil are categorized and presented with product examples and typical characteristics. Guidelines for oil products that should not be burned in boilers are listed. Air quality considerations and effects of burning waste oil are discussed, and an economic evaluation of burning waste oil is provided in Appendix C.

Sources of Waste Oil

The basic sources of waste oil generated at Naval activities are ships in port, aircraft fueling and maintenance activities, and other industrial/shop functions performed ashore. While over 80% of the volume of waste oil generated throughout the Navy is that obtained from ship bilge and ballast water brought ashore, activities having no port facilities may also generate enough waste oil to make its use as a supplemental fuel economical and worthwhile as an energy conservation measure. Currently, all activities are collecting and handling waste oils in some fashion. Consequently, the sources of waste oil can be identified, and quantities generated can be estimated. Collection and disposal may be conducted independently in various organizations or functional elements of an activity. Centralized collection and use of the waste oil as a fuel may pay dividends for the activity.

Ships in Port. The primary source of waste oil from ships is the bilge/ballast water pumped ashore. Most activities handle this waste by the use of Waste Oil Rafts (DONUTS), which perform an initial gravity separation function. The waste oil residual is either further treated by oil separation equipment, if available, or transferred to storage tanks for disposal (usually by sale).

Ships may also generate waste oil products that are brought ashore in drums and other containers. The types and quantities of this waste will vary, depending upon the type of ship. For example, industrial-type ships, such as tenders, aircraft carriers, and large amphibious ships, are the most likely generators of significant quantities. Examples of the wastes are contaminated fuels, turbine engine oils, hydraulic fluids, shop lubricants, carrier arresting gear and catapult hydraulic fluids, greases, and solvents of all kinds.

Aircraft-Related Functions. At Naval air stations, a major source of waste oil is the aircraft fueling and maintenance functions. Contaminated fuels that are unacceptable for reuse are a main source of waste oils. In aircraft maintenance shops, fuel tanks are purged, oils drained, etc., thus generating waste oils that must be disposed of. To a minor degree, these functions may be performed aboard aircraft carriers while in port and may generate some wastes to be brought ashore.

Industrial/Shop Functions. Large Naval activities, such as shipyards, Naval air rework facilities, and ordnance plants, will generate quantities of waste oil suitable for boiler firing. The use of these

waste oils as supplemental fuel will depend on the economics of collection, segregation, and treatment. Certain products that are used in industrial/shop facilities must not be burned. These are discussed later and are listed in Appendix A.

At nonindustrial activities, waste oil will be generated wherever internal combustion engine equipment is operated and maintained, as in transportation equipment shops, Navy Exchange service stations, automotive hobby shops, public works maintenance shops, and diesel generator plants.

Fuels which cannot be issued as specification fuels, but that become contaminated at storage and dispensing facilities, are another source of waste oil.

Oil products that will most likely be found in the waste oil are categorized into six types in Table 1. The basic characteristics of waste oil that are important from the standpoint of boiler fuels are flashpoint, viscosity, gravity, and any trait that presents a handling or burning problem (see discussions under Fuel Analysis in Part 3).

Boiler Fuel Requirements

Natural gas and liquefied petroleum gases are the first choices for heating fuels due to ease of use and handling characteristics, cleanliness, and subsequent low maintenance requirements. However, the use of less desirable fuels, such as fuel oils, has become necessary due to their availability and the shortage of natural gas. Waste oils generated at Naval activities are considered attractive substitutes or supplements for fuel oils.

Data for the total consumption of natural gas, liquefied petroleum gases, and fuel oils (GLO) and other energy sources for Naval shore facilities are presented in Table 2. It is seen that about 24% of the total energy consumed by Naval shore facilities is in the form of fuel oils. Generation estimates (Table 3) show that on an overall basis, the Naval shore facilities may substitute waste oils for at least 6% of the total Navywide fuel oil requirements. Depending on the particular activity, as much as 100% of the fuel oil requirements may be met with waste oil. These figures illustrate the potential for waste oil utilization as a fuel.

Boiler Fuels

Appendix A* of ASTM Specification D-396 classifies fuel oils into grades and places limitations on properties of the oils in each grade. These grades are described as follows:

Grade No. 1 is termed a light distillate oil because it is capable of being vaporized at relatively low temperatures and atmospheric pressure. Its intended use is almost exclusively for domestic heating where vaporizing-type burners convert the oil to a vapor by contact with a heated surface or by radiation. High volatility of the oil is necessary to ensure that vaporization occurs with a minimum of residue. This oil is a little

*Included in this technical note as Appendix B.

heavier than kerosene, but modern-day practice places both No. 1 fuel oil and kerosene in the same class.

Grade No. 2 is a heavier distillate than grade No. 1 and comes from the refinery fractionating tower after the No. 1 oil. Its intended use is in atomizing-type burners, which spray the oil into a combustion chamber where the droplets burn while still in suspension. This grade of oil finds use in both domestic and medium-capacity commercial/industrial applications where its cleanliness and ease of handling sometimes justify its higher cost over that of the residual oils.

Grade No. 4 is a variable and complex mixed classification. It is usually a light residual but is sometimes a heavy distillate. This oil is of lower viscosity than No. 5 or No. 6 fuel oils and is intended for use in burners equipped to atomize oils of higher viscosity than domestic burners can handle. Its limited service includes use in small boilers of schools and apartment buildings, forging furnaces, and low-heat installations. Its viscosity range allows it to be pumped and atomized at relatively low temperatures requiring no preheating for handling except in extremely cold weather. A refinery usually does not attempt to produce this grade of oil because of its low sales volume.

Grade No. 5 is a residual fuel of intermediate viscosity for burners capable of handling fuel more viscous than grades 1, 2, or 4 without preheating. Preheating may be necessary for use in some types of equipment for burning and for handling in colder climates.

Grade No. 6 is a heavy, black residual of the refining process and sometimes referred to as "Bunker C." This is a high viscosity oil used primarily in commercial and industrial heating. It requires preheating in the storage tank to permit pumping and additional heating at the burner to permit atomization. The equipment and maintenance required to handle this fuel usually prevents its use in small installations.

Table 2 of ASTM D-396 lists the various grades of fuel oils with their respective specifications (see Appendix B).

Air Quality Considerations

The chemical elements that characterize combustion of fuels in air are carbon, hydrogen, nitrogen, oxygen, and sulfur. The primary products arising out of the complete combustion of a fuel are carbon dioxide (CO_2), water (H_2O), and nitrogen oxides (NO and NO_2), plus sulfur oxides (SO_2 and SO_3) if sulfur is present in the fuel. CO_2 and H_2O are considered harmless combustion products in the exhaust gases.

The Environmental Protection Agency (EPA) has identified six exhaust gas pollutants: (1) particulate matter, (2) sulfur dioxide, (3) nitrogen oxides, (4) carbon monoxide, (5) hydrocarbons, and (6) oxidants.

Particulate matter is the nongaseous portion of the combustion exhaust consisting of all solid and liquid material (except water droplets) suspended in the exhaust gases. It is generally defined as any material that would not pass through a very fine filter. Particulate matter can be composed of unburned fuel, sulfur compounds, carbon, ash constituents in the fuel (including many toxic metals), and even non-combustible airborne dust entering the combustion air system. Current devices to remove particulate matter include filtration, mechanical separation, and electrostatic precipitation.

Sulfur dioxide (SO_2) is a nonflammable, colorless gas that can be "tasted" in concentrations of less than 1 ppm in the air. In higher concentrations it has a pungent, noxious odor. SO_2 is formed in the combustion process when sulfur contained in the fuel combines with oxygen from the combustion air. SO_2 and SO_3 comprise the total oxides of sulfur, generally referred to as SO_x . SO_3 is usually no more than 3% to 5% of the total SO_x generated. Essentially all sulfur contained in the fuel is converted into SO_2 , and SO_3 and is not highly affected by boiler operating conditions of design.³ Although regulating the quantity of sulfur in the fuel is the primary method of controlling SO_x emissions, stack gas scrubbers can also be effective in removing SO_2 from the combustion exhaust.

Nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), are generated in the combustion process. These compounds are referred to as NO_x . NO is a colorless, odorless gas that is not considered a direct health threat in the concentrations found in the atmosphere. NO_2 is considerably more harmful and comprises typically 5% or less of total NO_x emitted from boiler stacks. Once in the atmosphere, however, a large fraction of the NO is converted into NO_2 . NO_2 is a yellow-brown colored gas having a pungent, sweetish odor. NO_x is formed spontaneously during the combustion process when oxygen and nitrogen are present at high temperatures. Because all three of these (oxygen, nitrogen, high temperature) are essential to the combustion process, it would be difficult to prevent NO_x formation. Nitrogen is present in the combustion air and fuel itself. Lower peak flame temperatures, reduced excess oxygen, or a combination of both have been effective in reducing NO_x formation. Future techniques will scrub NO_x from the exhaust gases before entering the stack.

Carbon monoxide (CO) is a product of incomplete combustion. Its concentration in exhaust gases is usually sensitive to boiler operating conditions. Improper burner settings, deteriorated burner parts, and insufficient air for combustion can cause high CO emissions. CO is toxic, invisible, odorless, and tasteless.

Hydrocarbons also are indicative of incomplete combustion and can be greatly reduced by proper boiler operation. However, hydrocarbons cannot be entirely eliminated; trace quantities will nearly always be present, regardless of boiler operation. Hydrocarbons are active ingredients in the formation of photochemical smog, and under certain atmospheric conditions can be transformed into other potentially more hazardous derivatives.

Oxidants are oxygen-bearing substances that take part in complex chemical reactions in polluted atmospheres. Photochemical reactions that are intensified in the presence of sunlight involve nitrogen oxides (NO_x) and reactive organic substances (hydrocarbons and their derivatives) as principal chemical ingredients. These react to form new compounds like ozone and PAN (peroxyacyl nitrates), which are the major oxidants in smog. While ozone and PAN are not generated in the boiler, the principal ingredients (especially NO_x) are supplied by the exhaust gases.

The environmental air quality considerations discussed apply whether or not waste oil is burned. However, parameters for emission control may change when waste oil is being burned due to the varied properties

of the waste oil. When burning waste oils, depending on the contaminants in them, harmful combustion products, such as halogenated compounds, may be produced. Therefore, caution must be exercised to prevent halogenated waste materials from entering the waste oil.

Restrictions on Use as Fuel

The majority of waste oils considered here are petroleum-based products. Synthetic/chemical- (nonpetroleum-) based products require segregated collection. Appendix A lists synthetic/chemical-based waste oils, low flashpoint materials, and halogenated solvents that should not be burned. Special precautions are required to avoid dumping solvents or residues that contain halogens into waste oils being collected for boiler firing. Shops must segregate all halogenated compounds when practical, because high enough concentrations may result in accelerated corrosion of boiler components and produce unhealthful stack emissions. This type of waste can be added to waste oils only after the individual batch has been determined to be free of halogen. If the oil fails the tests outlined in Part 3, it is probably due to improper segregation and should be disposed of separately. Suspect materials are trichloroethane (O-T-620C), trichlorotrifluoroethane (MIL-C-81302), constant speed drive fluid (MIL-S-81087), and various cleaning compounds.

NOTE

Used lubricating oils should be re-refined whenever possible. DOD Directive 4165.60 incorporates formal policy on methods for disposal of used lubricating oil. DOD guidance consists of two methods: (1) examine the feasibility of re-refining in order to conserve natural resources and (2) if re-refining is not economical, use it as a boiler fuel in order to recover the energy content. Other methods, such as use for dust control, are not allowed. If used lube oil is burned as a boiler fuel, a written justification which outlines the reason for not re-refining the oil must be prepared.

Because of their nature, Type A products in Table 1, such as gasoline, JP-4, and used solvents, are undesirable as boiler fuels. Low flashpoint characteristics make these materials hazardous to handle and burn. Likewise, type F wastes create a hazard in handling and burning and should not be used as a substitute fuel.

Type B, C, D, and E wastes can be utilized readily as a burner fuel by blending with the fuel oil in use or by providing a separate waste oil burner in the boiler. Certain basic requirements must be met, but in general, a wide range and large quantity of waste oil from these types can be reused with no resulting mechanical or environmental problems and with negligible loss in heat generation.

Economics of Burning Waste Oil

The economics of burning waste oil as a supplemental fuel are of interest in public works management and in justifying facility projects for utilization of waste oil. While the specifics will be different for

each Naval activity, most of the economic factors are common, and guidelines for calculating costs and savings can be determined (see Appendix C for elements to be considered). The following functions are required for using the waste oil as a fuel and for selling it from a central storage tank.

Burning as a Fuel:

- collection and segregation
- transportation and centralization
- water and sludge removal
- testing
- storage
- mixing/blending

Sale:

- collection
- transportation and centralization
- water and sludge removal
(not required in some cases)
- storage

The following comments on the functions of these two alternatives apply to most activities:

- The cost of collection and transportation of the waste oil will be the same for both methods of disposal.
- Certain waste oil products must not be burned and must be segregated and handled separately. Under many sale contracts and other disposal methods this segregation is not required. Consequently, there may be a unique cost of segregation associated with burning.
- At most sites, the only treatment required prior to burning or sale is gravity separation of the water and solids. The costs will be about equal for both cases.
- The cost of storage for sale is unique. A tank must be dedicated to waste oil. If water/solids removal is accomplished elsewhere, the waste oil to be burned may be placed directly into boiler fuel tanks. For convenience, a separate dedicated waste oil tank may be installed at the boiler plant, and the costs of storage will be essentially equal for any disposal alternative.

Cost of Burning Waste Oil. Based on the above, typical cost and savings factors for use in calculating the economics of burning the waste oil are as follows:

Recurring Costs -

- Segregation required only for burning.
- Testing to determine safe burning properties.
- Mixing/blending of waste oil with new fuel, if required.
- Price that waste oil could be sold for under contract. (If waste oil is burned, the income loss from potential sale is a cost of burning.)

One-Time Costs -

- New facilities and equipment required to use waste oil as a fuel.

Savings -

- Cost of new fuel not purchased due to burning waste oil.

If the savings in fuel purchases are greater than recurring costs, the payback period for the one-time cost can be calculated (see Appendix C for details). The Energy Conservation Investment Program (ECIP) Criteria of NAVFAC Instruction 11010.14M also includes similar guidelines for economic evaluation and cost savings analysis and may be used as it applies (see also Ref 4).

ECIP Considerations

The Department of Defense (DOD) Energy Conservation Investment Program (ECIP) (Ref 4) is a Military Construction (MILCON) funded program for retrofitting existing DOD facilities to make them more energy efficient while providing substantial savings in utility costs. While the ECIP is not fully applicable to the burning of waste oils as boiler fuel (usually no retrofitting of existing facilities), it may be beneficial and relevant to consider the purpose and goals of the ECIP when evaluating the cost/savings involved.

Energy-to-Cost Ratio. Under the ECIP (Ref 4), all projects must produce an energy-to-cost ratio (E/C) of MBtus of energy saved yearly per thousand dollars (\$K) of current working estimate (CWE) investment equal to or greater than a specified minimum value.

$$E/C = \frac{\text{MBtu saved/yr}}{\$K \text{ CWE}} \geq \text{the specified minimum*}$$

This may not be directly applicable, as we are anticipating a net saving rather than a net cost as we use waste oils in place of some or all of the regular fuel oil.

Benefit/Cost Ratio. Also, there is an ECIP requirement that the benefit/cost ratio exceed 1.0 for each project. This, too, may not be directly applicable for the same reason: we are anticipating a net saving rather than a net cost.

Simple Payback Period. In some cases there may be an initial investment (e.g., for waste oil storage tanks or facilities for mixing or blending waste oil with fuel). In these cases, a simple payback period may be calculated as outlined in Appendix C.

*FY82 = 19; FY83 = 18; FY84 = 17.

PART 3. PROCEDURES FOR BURNING WASTE OIL AS BOILER FUEL

This part discusses segregation and collection of waste oil, centralized storage, treatment, quality control, and delivery to the boiler plant. The specifics will vary with each shore activity; therefore, only general discussions for each type of source are included. Fuel analyses in terms of physical/chemical constraints and tests for evaluation of the waste oil are prescribed. Blending and viscosity control of the waste oil are described to provide insight into necessary operational changes, modifications to existing equipment, and additional equipment required. Unique maintenance and operational requirements that may be encountered are discussed, and recommendations regarding recordkeeping for documentation of future waste oil burning experience are provided.

Segregation

Presence of caustic, acidic, and halogenated compounds in waste oils may cause corrosion to fuel system components and produce combustion products which are harmful to the boiler and which may pollute the environmental air. Such compounds may come from detergents, industrial wastes, solvents, cleaning fluids, synthetics, etc. Proper segregation not only will minimize the possible hazards due to undesirable contaminants but also will lessen the effort and cost of treating the waste oil.

The segregation of nonburnable* wastes at the source is relatively simple. Oil products that must be segregated are listed in Appendix A. The identification and separate collection of nonburnable products at shore industrial areas and shops is within the control of the activity and can be accomplished through indoctrination of personnel and by providing facilities that make segregation easy. The segregation of those wastes aboard ship before they enter the bilge is not within the control of the shore activity, but there are steps that can be taken to improve the quality of the waste pumped ashore.

Ship Waste Oil Segregation. Segregation is not applicable to the oily wastewater pumped from bilges. Any undesirable contaminants present in that waste will have to be accepted and, once the waste is dewatered, testing must determine if the waste oil is suitable for burning. In most cases, nonburnable type wastes in the oil will be so diluted by quantity that no problems will be encountered with burning. Nevertheless, if the hazardous oil products in use aboard ships can be identified and publicized and the ships prevailed upon to segregate such wastes and move them ashore separately, the quality of the waste oil will be improved. Waste oils brought ashore in properly labeled drums/containers can be segregated at the source if the products are identified ahead of time and containers provided.

*As boiler fuels.

Segregation in Industrial Areas. If an aggressive program for collecting and burning waste oil is established by an activity, publicizing the results in dollar savings and energy conservation will help in obtaining cooperation in segregation. Containers and collection at necessary frequencies must be provided to lessen the workload of separate handling. Once it becomes standard procedure in a shop to handle certain wastes separately, the procedure will continue. Original containers may be saved and reused for waste collection. Drums, with appropriate signs or labels, may be placed in or near shops for disposal of "dirty" and "clean" waste oil products. As with other types of recyclable products (such as paper and metals) the difference in time, labor, and trouble required to reclaim the item rather than throw it away is very small once it becomes part of the routine.

Centralized Storage

Burnable waste oil should be centralized in storage prior to delivery to the boiler plant or contractor-receiving points. It is costly to have a waste oil buyer pick up small quantities at many locations. Tank trucks or trailers may serve as mobile storage for collecting and storing the waste oil between source and boiler plant.

Unless the waste oil is stringently treated prior to burning, or unusually clean when collected, gravity separation will be required to remove water and solids. Large quantities of "clean" waste oil generated at one time should be delivered directly to the boiler plant when possible to avoid further degradation by mixing with other waste oils (e.g., contaminated jet fuel declared unusable for aircraft).

Treatment -- Water/Sludge Removal

Waste oil may contain varied amounts of water, sludge, and solids. Excessive water in oil may cause flame out; sludge and solids may plug up the fuel system, cause excessive wear in nozzle tip and pump components, etc. They must be removed from the waste oil before it can be safely fired in a boiler. At present, an oil that contains no free water* and that can pass through an 80-mesh screen filter is considered reasonably adequate for boiler firing.

Water, sludge, and solids may appear in the waste oil either in a form more or less separated from the bulk of the oil or suspended in it in various emulsified states. In general, they may be removed simply by gravitation separation. By leaving the oil in a tank undisturbed for enough time, they will eventually settle at the tank bottom and can be easily removed. When sufficient time is not available, the gravitation separation process may be accelerated by heating up the oil to some safe temperature (e.g., with a steam coil heater to 150°F) or by using a centrifuge. If the waste oil appears to be a stable emulsion (having poor demulsibility by the above methods) mixing it with light fuels such as contaminated JP-5 or diesel will help accelerate the demulsification

*Refer to water visibly separated from the oil as distinguished from water suspended in the oil in an emulsified state.

before the gravitation separation process. (The amount of light fuel to be used depends on the nature of the emulsion. Adding one part of fuel in five parts of waste oil would be a good starting point.)

Fuel Analysis

Waste oils obtained through proper segregation and water/sediment removal as described above are mixtures primarily of hydrocarbons. Other than the appearance, they should have similar properties as regular fuel oils. To illustrate, the characteristic properties of a variety of randomly selected oil samples were measured and the results are shown in Table 4. Since specifications are concerned only with ranges and limits, fuel oils of the same grade are likely to have different property values. The variability of properties of waste oils is expected to be even greater. Fortunately, detailed knowledge of these oils is usually unimportant, and only the properties directly affecting the safety and operations of a boiler need be determined occasionally. These properties are discussed below (see Appendix B for the applicable ASTM test methods):

1. Gravity (or degrees API). This is an indirect measure of the fuel density. The carbon-to-hydrogen ratio and heating value of fuel oils can be reasonably well estimated from their gravities as shown in Figure 1. Carbon-to-hydrogen ratio affects the combustion air requirements (the fuel-air ratio), and heating value affects the burner firing rate. Adjustment of the burner for efficient burning, therefore, will be required when fuels of different gravities are fired.
2. Viscosity. This is a measure of the resistance of the oil to flow and atomization. For a burner to function properly, the fuel must be within a certain viscosity range. Since viscosity is highly temperature dependent, this is achieved by heating the oil to the appropriate temperature (see "Viscosity Control" later).
3. Flashpoint. This is the lowest temperature at which a fuel may be ignited under specified conditions. It is, therefore, a measure of safety. The minimum flashpoint for commercial grade fuel oils is 100°F (see Appendix B).
4. Water and Sediment. Water in oil may cause unstable flame or flame out. Sediment may cause fuel system blockage and accelerated wear. Excessive amounts of these must not be tolerated. If the waste oil collection procedure described earlier is followed, no difficulty should be encountered during burning.
5. Chemical Contamination. Due to the uncontrollable nature of individual practice in waste oil collection, contamination by undesirable chemicals may still be possible. The following simple methods may be used to periodically determine the quality of the waste oil.

- (a) Copper Corrosion Test. Maintain the oil at 50°C and immerse in it a properly polished sample copper strip for 3 hours. The relative corrosiveness of the oil is determined by the extent of tarnishing of the strip. For example, the maximum allowable tarnish designation number for commercial grade No. 1 and No. 2 fuel oils is 3, and no maximum is specified for heavier oils. No. 4 tarnishing was reported from occasional tests of the waste oils generated in San Diego and Norfolk areas. No adverse experience on these oils has been reported, however.
- (b) Copper Wire Test. The undesirable contaminants found in waste oils are primarily chlorinated compounds. This test will determine the acceptable level of chlorine in the waste oil.

A clean copper wire is heated in a clear, blue gas flame to red heat until no green shows in the flame. The wire is dipped while still hot into a sample of waste oil and then put back into the flame. No green shall show in the flame. For practice, a blend of 1% trichloroethane in DFM or other distillate fuel may be used as an example of an oil which fails this test. The oil sample should be purged of any sodium chloride prior to the test by washing with freshwater.

If an oil fails this test, it is probably due to improper segregation. It can be salvaged by blending it into known good quality oil so that it becomes acceptable or is disposed of in accordance with Reference 5.

6. Sulfur Content. Maximum allowable sulfur in oil is regulated by local authorities (e.g., < 0.5% in California). Since the main ingredients of waste oil (e.g., JP-5, DFM, lubricating oil) are primarily low sulfur materials, the sulfur content of waste oils, therefore, is usually low. Occasional determination of the sulfur content in waste oil would be adequate.

A sufficient overview of the waste oil properties can be achieved if testing is performed once or twice each month for a 6-month period. Although the physical/chemical properties of the waste oil may vary considerably between shore activities, the properties should remain fairly uniform for any one given activity. If the above properties are known, the waste oil is then somewhat predictable and necessary adjustments for burning and blending can be properly accomplished.

Blending

Two possible methods of blending are considered here: direct and in-line blending. Direct blending is the addition of the waste oil directly into existing fuel oil tankage. If the waste oil being added to the tank is lighter than the normal fuel oil, it should be pumped in at the bottom of the tank. The lighter oil will tend to mix as it rises through the heavier oil. If the waste oil is heavier than the fuel in the tank, it should be pumped in on top. The heavier oil will tend to

mix as it falls into the fuel. The tank contents should then be circulated to achieve a homogeneous mixture. Direct blending tests show that results are predictable, and no special attention is required to burn the waste oil, except to adjust the temperature of the blend so that its viscosity is nearly the same as that of the regular fuel oil.

In-line blending is simple and practical with either distillate or residual fuels. Even though additional equipment is necessary, the effort and expense are minimal. A proposed waste oil supply and in-line blending scheme is shown schematically in Figure 2. In this scheme, the waste oil is introduced into the suction side of the main fuel pump of the existing system to insure thorough mixing. Temperatures are taken at three locations, and a sampling port is provided downstream of the pump so that the waste oil concentration can be measured by either the "Temperature Method" or the "Specific Gravity Method" described below. The low-pressure pump near the waste oil tank is used for stirring the waste oils in the tank, as necessary, to insure a homogeneous mixture. It may be used during actual boiler operation. Experience gained thus far shows that in-line blending is simple to implement and works satisfactorily.

Specific Gravity Method. Let γ_1 , γ_2 , and γ_3 be the specific gravities, respectively, of the regular fuel oil, waste oil, and their blend at the same temperature. Assuming constant volume mixing, the waste oil concentration in percent would be:

$$\frac{\gamma_3 - \gamma_1}{\gamma_2 - \gamma_1} \times 100\% = \% \text{ of waste oil in blend}$$

For this method, an ordinary hydrometer, a thermometer, a glass cylinder, and a sampling port close to the burner nozzle in the fuel system will be required. This is a one-time measurement, but the accuracy is good, the procedure is simple, and the initial investment is minimal. The accuracy of this method increases with the difference between γ_1 and γ_2 .

Temperature Method. Let T_1 , T_2 , and T_3 be the temperatures, respectively, of the regular fuel oil, waste oil, and their blend. If these temperatures are measured at locations fairly close to one another, and assuming that the specific heats of the oils are the same and the mixing takes place without the loss or gain of heat, by conservation of energy the waste oil concentration may be calculated as follows:

$$\frac{T_3 - T_1}{T_2 - T_1} \times 100\% = \% \text{ of waste oil in blend}$$

Some inherent errors exist due to the assumptions used. This method is ideal for continuous monitoring if automatic recording devices are used and is particularly helpful when blending oils of nearly equal specific gravities.

Viscosity Control

Waste oil added to regular fuel affects the viscosity of the blend, the fuel flow rate, and nozzle spray characteristics. To minimize the requirements for burner adjustments, the firing temperature of a blend should be controlled so that its viscosity is nearly the same as that of the regular fuel oil at its normal firing temperature. The viscosity variation with the temperature of typical fuel oils may be estimated by using the viscosity-temperature charts for liquid petroleum products in Reference 6. A working chart for determining the approximate operating temperature of fuel oil blends is shown in Figure 3.

Figure 3 consists of two separate graphs. The one on the left is used to determine the viscosity of a blend of two oils of different viscosities (all in SUS* at 100°F), and the one on the right shows the temperature variation of viscosity for oils whose viscosities at 100°F are known. The use of these graphs is illustrated in the following example:

EXAMPLE

A burner is designed for burning a type of heavy fuel oil having a viscosity of 1,000 SUS at 100°F. This oil is heated to 180°F to achieve satisfactory firing. A light waste oil on hand, which has a viscosity of 50 SUS at 100°F, will be blended into the heavy fuel oil to supplement the boiler fuel. To fully utilize this light waste oil, its concentration in the blend is determined to be 30%. What is the satisfactory operating temperature of this blend?

From the right-hand graph of Figure 3, along the line labeled 1,000 SUS, we find that the viscosity of this oil at 180°F is 125 SUS. From the left-hand graph, the viscosity of a blend of 30% waste oil is slightly less than 300 SUS. Again on the right-hand side of the graph, along the line labeled 300 SUS, we find that to attain 125 SUS the oil should be heated to 140°F. This is shown in the graphical construction.

Burner Modifications

If the firing temperature of the blend is adjusted to compensate for the change in viscosity as discussed above, no special modifications to burner equipment are required to fire waste oil blends. Minor adjustments are sometimes necessary, however, to correct unstable combustion and smoke emission similar to the routine adjustments for firing clean fuel. Other than relatively high ash accumulation when firing blends of high concentrations of used lubricating oil, no apparent emission problems should be encountered (Ref 1, 2, and 3). Therefore, no special provisions should be required to monitor stack gas emissions. To insure efficient boiler operations, oxygen is the only critical item for stack gas monitoring.

*Saybolt Universal Seconds.

Unique Maintenance and Operational Requirements

Generally, waste oils free of water and sludge can be satisfactorily fired in boilers either straight or in blends with regular fuel oils. However, maintenance requirements are higher for blends with higher concentrations of used lube oils.* Problems that may be encountered in burning of waste oil are:

- Fine lint buildup in barrels and nozzles which are hard to clean
- Substantial ash buildup in the fire box, deposits on boiler tubes, and fly ash
- More frequent cleaning of fuel strainers, up to four times as often
- Rise in flue gas temperature due to deposit buildup on heat transfer surfaces
- Excessive wear of fuel pumps and nozzle tips, inoperative valves, plugged strainers, and flow passages
 - (a) Rotary vane pumps are especially intolerant to solids; damage includes scored liners and pitted vanes
 - (b) Burner tips become enlarged, elongated, and pitted
- Increased firing rate due to the lower Btu value of the waste oil
- It may be necessary to preheat the boiler with natural gas

To minimize maintenance, if used lube oil must be burned, a concentration of less than 25% in the blend is recommended.*

Large amounts of water and bottom sediment are commonly found in waste oils. Excessive amounts of water in oil can cause flameouts. Excessive solid concentrations can cause accelerated wear and damage to boiler equipment. Removal of water and solids from the waste oil prior to burning is essential. Gravity settling is usually satisfactory. Accelerated settling may be achieved by heating the oil, blending with other light oil, or using a centrifuge.

Even though the waste oil cannot be expected to meet the standard specification of fuel oil, it can be used satisfactorily, provided some precautions are taken. Synthetic- and chemical-based liquids may be hazardous in handling and burning. These materials must be segregated at the source of generation or collected and disposed of according to Reference 5. Identification of these liquids is discussed in Part 2. It is necessary that the waste oil be free from halogenated material to

*Burning of used lube oil must comply with DOD Directive 4165.60. See NOTE on page 7.

prevent toxic gas emissions and accelerated corrosion of the fire side surfaces of the boiler. Testing of the waste oil to determine the presence of such contaminants is discussed earlier.

Recordkeeping

In order to (1) further its use, (2) improve upon current technique and procedure, and (3) show achieved dollar savings, information pertaining to the utilization of waste oil as a supplemental fuel should be included as part of the record for boiler operations. A recommended outline of information to be recorded is listed below:

- I. Sources of waste oil
- II. Quantity of waste oil burned
- III. Quality control
 - A. Methods of segregation
 - B. Treatment methods
 - C. Physical/chemical testing
 - D. Blending methods
- IV. Effects of use and unique maintenance and operation requirements
 - A. Problems in operation
 - B. Unusual maintenance requirements
 - C. Equipment modification and adjustment requirements
 - D. Stack emissions
- V. Achieved savings

PART 4. REPORTED EXPERIENCE USING WASTE OIL AS BOILER FUEL

The information presented here was obtained through a limited survey, and its accuracy and completeness depend on the effectiveness of the survey communications, the knowledge of the respondent, and the rapport and understanding achieved during the communications. It is, therefore, the best obtainable at this time and should be considered as a "lower limit," with additional data and information yet to be obtained. Periodic updating of this information will be required as circumstances, equipment, and operation of the activities continually change. The information does, however, depict the status of waste oil generation and burning by Navy activities and can serve as guidelines for planning and implementing the use of waste oil as boiler fuel.

Survey of Navy Activities

Waste oil has been burned routinely or used as a supplementary boiler fuel in tests at a number of military activities. The experience gained can be of value to other activities investigating or considering its use. Over a period of 2 years, NCEL has conducted surveys by telephone and by mail of Navy and Marine Corps shore activities on waste oil generation and utilization. As indicated earlier, of the total 592 Navy/Marine Corps activities with UIC numbers, 325 indicated fuel oil usage. These 325 activities are located in 153 geographical locations. Successful telephone contacts were made with Public Works officers and environmental engineers at 94 of the 153 locations. These were followed by survey forms with 130 returns.

Activities burning waste oil reported no major problems. Minor problems encountered when burning large amounts of waste oil included fireside deposits and plugging of burner tips. Boiler operations were kept efficient by slightly increasing regular maintenance duties (e.g., cleaning or changing strainers and burner tips).

Narrative Summaries of Experience with Burning Waste Oils as Boiler Fuel

Summaries of the information gathered from the survey and results of experience by the Army and Air Force are presented in the paragraphs that follow. Where indicated, the information pertains primarily to the individual activity identified (e.g., Camp S.D. Butler, Japan). Where only areas or locations are indicated (e.g., Charleston, S.C.), the information pertains to a group of activities in the area.

U.S. Army, Aberdeen Proving Ground, Md. During 1968-1972, the Army burned approximately 40,000 gallons of used lube oils each year in a boiler plant (60 MB/hr, water tube boiler with steam atomization burner) at Aberdeen Proving Ground. This oil was simply dumped into the F06 tank at a proportion of 1:3 (or 25% used lube oil in the mixture). Since no deliberate blending or mixing was attempted, the exact concentration of the blend may have varied considerably. No difficulty was encountered. In 1972, when low sulfur oil had to be used to limit the SO₂ emissions, two series of short-term tests were conducted burning F02 and used lube oil blends using a rotary cup burner in a 5.4 MB/hr

fire tube boiler. The results showed that with up to 27% used lube oil in the blend, no stack emission problem was encountered.

NAVSTA Adak, Alaska. This activity collects waste oils generated throughout the island. In FY80 this amounted to 34,000 gallons, and in FY82, approximately 26,000 gallons. These oils were generated from power plants, ships, and shops, and consisted of contaminated JP-5, used crankcase oil, solvents, and miscellaneous waste oily products. Except for 1,000 gallons used for firefighting training, the oil was burned in boilers by blending one part of crankcase oil into four parts of contaminated JP-5. The total waste oil generated could replace 0.3% of the total fuel oil consumption.

U.S. Air Force Tests (Ref 7 and 8). A systematic test series was conducted by the Air Force. Used lube oils containing aviation piston engine oils, synthetic turbine lubricant, hydraulic fluid, Stoddard solvent, etc., were mixed with F02 and F06 at concentrations of 0.1%, 1%, and 10%. These blends were then fired for 30 minutes each to determine the firing characteristics. No difficulty was encountered, and no ill effects (e.g., emissions, corrosions, degradation of boiler systems) were observed. A series of 2- to 3-hour tests were then conducted at 5% concentration. Satisfactory firing was achieved, and no increase in particulate emissions was measured. As a result, long-term in-service boiler tests were recommended. Tests of this nature were conducted at three Air Force bases. Up to 26% used lube oil in F02, 6% JP-4 in F05, 16% JP-4 in F02, 4% and 11% of 50/50 JP-4/used lube oil, respectively, in F02 and F05 oils were tested. Results showed that relatively clean burning fuel (e.g., JP-4) mixed in relatively dirty fuel (e.g., F05) would not adversely affect emissions. But relatively dirty fuel (e.g., used lube oil) mixed in clean fuels will significantly increase the particulate emissions although the emissions are still below standards. Overall, the combustion performance either remained the same or improved.

Andros Island, Bahamas. This area generates 300 gal/mo of used SAE 40 lube oil from diesel engines at the power house. About half of this waste oil is burned by direct blending in four Cleaver Brooks, diesel-fuel-fired, fire tube boilers, ranging from 15- to 60-hp boilers. These boilers have pressure atomizing burners with fail-safe controls and operate on a load factor. Waste oil is mixed with diesel engine fuel and fired in the boiler system direct. The total waste oil generated could replace 0.2% of the total fuel oil consumption.

Bangor, Wash. This area generates and burns 156,000 gallons of waste oil a year at the submarine base (54% from ship and the rest from shops). Waste oil, primarily contaminated F02 and diesel, is collected and sent to NSC Puget Sound by base support haulers. Puget Sound Manchester treatment facility purifies the waste oil prior to burning. The total waste oil generated could replace 30% of the total fuel oil consumption.

Barking Sands, Hawaii. This activity generates 6,200 gallons of waste oil a year, and an estimated 96% of the waste oil collected is burned. Used lube oil from aircraft, shops, and automotive vehicles is

blended in-line with DF2. A filter separator is used in the waste oil feed line to control contaminants. The activity had experienced excessive corrosion on intake and return lines before using the filter. Burning takes place in a 15-hp fire tube boiler with an automatic full modulation control. The boiler operates on a load factor with a waste oil/fuel oil ratio of 1:10. The total waste oil generated could replace 8% of the total fuel oil consumption.

Bethesda, Md. This area generates 5,600 gallons of waste oil a year, with an estimated 2% being burned. Used lube oil from automotive equipment, gear boxes, and air compressors is blended with F06 and burned in five water tube boilers ranging in size from 30,000 to 50,000 lb/hr. All boilers have air atomizing nozzles with semi-automatic controls and operate in a continuous mode. The total waste oil generated could replace 0.1% of the total fuel oil consumption.

Brunswick, Maine. This area generates 8,600 gallons of contaminated JP-5 a year from aircraft and shop waste of which 1,200 gallons are blended directly with F06 in the fuel storage tank, and burned in six water tube boilers, ranging in size from 26,000 to 60,000 lb/hr. These boilers all have mechanical atomizing burners with automatic controls. The total waste oil generated could replace 0.3% of the total fuel oil consumption.

Camp Pendleton, Oceanside, Calif. This Marine Corps base generates and sells 96,000 gallons of waste oil a year from primarily shop operations. Over 384,000 gallons of FOR from the Point Loma Fuel Depot, San Diego, are burned annually, along with 6,000 gal/mo of waste oil from NAVSTA. There are 514 boilers of sizes from a fraction to 20 MBtu/hr, with an estimated 90% being fire tube type. The operating mode is intermittent. During winter, the load factor is 90% at 15 hr/day. During summer, the load factor is 50% at 8 hr/day. Two 25,000-gallon storage tanks are being converted into waste oil gravity separation/storage tanks. The total waste oil generated could replace 6% of the total fuel oil consumption.

Camp S. D. Butler, Japan. This base generates from 50,000 to 60,000 gallons of waste oil annually. Sources include aircraft, shops, and motor pools. An estimated 10,000 gal/yr of contaminated DF2, JP-4, kerosene, and NSFO are being burned intermittently at the Marine Corps Air Station. Most of the 190 boilers are the dry back, marine, and locomotive types. The boilers range in size from 0.14 to 2.13 MBtu/hr. The total waste oil generated could replace 2% of the total fuel oil consumption.

Charleston, S.C. This area generates 1,300,000 gallons of waste oil annually, primarily from bilge and ballast waste from the Naval Shipyard. Aircraft and hydraulic training devices are additional sources. An estimated 20% of the waste generated is recycled through an oil-water separator and blended into NSFO and burned as boiler fuel. The viscosity of the blend is constantly monitored to keep it within required specifications for NSFO. Since FY80, 1.2 million dollars have been credited to NAVSUP because of this burning. The total waste oil generated could replace 23% of the total fuel oil consumption.

NWC China Lake, Calif. In 1978 and 1979, NCEL and NWC China Lake conducted a series of controlled tests burning waste oil in one boiler. The boiler utilized was a single-burner, water tube boiler producing 125-psi saturated steam at 20,700 lb/hr rated capacity. These tests were run blending the waste oil in concentrations of 8% to 90% with FO6. Control tests were also conducted with FO6 alone and burning 100% waste oil. The results were reported in Reference 2.

NWC China Lake generates approximately 3,300 gallons of waste oils per month that are comprised primarily of contaminated JP-4, JP-5, diesel fuels, and used lubricating oils. The mixture of these oils is a dark-colored liquid resembling light fuel oil and is somewhat heavier and higher in viscosity than diesel fuel. This material had been used in the past for firefighter training and dust control. Only high flashpoint waste oils (e.g., used lubricating oils, contaminated JP-5 and diesel fuels) were used for the tests. Low flashpoint and other materials (e.g., contaminated JP-4, gasoline, solvent) were collected separately for firefighters' training and were not mixed with the high flashpoint materials.

The NWC waste oil resembled a light grade fuel oil. After removal of water and solid contaminants, this waste oil was satisfactorily fired in boilers, either straight or in blends of any concentration with the regular FO6. To minimize the requirement for burner adjustments, the firing temperature of a blend was controlled so that its viscosity was nearly the same as that of the regular fuel oil at its normal firing temperature. No operational or environmental emission difficulties were encountered due to the presence of waste oil during either batch or in-line blending tests. In-line blending was successfully achieved by combining two oil streams using a "T" arrangement. The total waste oil generated could replace 8% of the total fuel oil consumption.

Crane, Ind. This area generated 9,615 gallons of used motor oil from June 1981 to June 1982. About 23% of this oil was burned in three water tube boilers: one at 18,000 lb/hr and two at 20,000 lb/hr. All three have air atomizing burners and operate in a continuous mode. Waste oil is blended directly with FO6. The total waste oil generated could replace 0.3% of the total fuel oil consumption.

El Toro, Calif. This area generates 195,000 gallons of waste oil annually. An estimated 75% of this used motor oil, AVGAS, and kerosene is burned. Of the 54 water tube and fire tube boilers reported, all were gas/oil fired with automatic controls and air atomizing burners. Operating modes are both continuous and intermittent. They have had approximately 3 years of experience burning waste oil. The total waste oil generated could replace 70% of the total fuel oil consumption.

NAS Fallon, Nev. This air station generates approximately 59,000 gallons of waste oils per year, of which about 94% is JP-5 from aircraft maintenance hangars and 6% is lubrication oils from transportation shops. About 44,000 gal/yr of the JP-5 is burned directly in 23 boilers 15 to 200 hp in size - three water tube continuously operated 448-hp boilers and 20 intermittently operated fire tube boilers. Four of the burners use air atomization, and 19 use mechanical pressure

atomization. The waste oil was burned by directly dumping into existing fuel tanks. About 10,000 gallons of the JP-5 is used for firefighting training. The 3,600 gallons of lube oils and 2,000 gallons of the JP-5 are used for weed and dust control. The total waste oil generated could replace 6% of the total fuel oil consumption.

Guam. In FY80, PWC Guam reported generating two types of waste oil. They reported further that approximately 8,000 gal/yr of used lube oil results from oil changes of diesel engine generators. As much as 600,000 gallons of contaminated DFM each year is generated from pipeline purging at the tank farm. No quality assurance measures are taken since the fuel is not really dirty but contains water and, maybe, small amounts of F06. This waste oil is not burned on a regular basis but, rather, only when a supply accumulates or becomes available from the tank farm. It is direct-blended into existing F06 tankage by first filling the tank half full with the waste oil and then filling the tank with F06. This oil is utilized by three 200,000-lb/hr and three 150,000-lb/hr boilers using approximately 190,000 gal/day of fuel oil. No modification to existing equipment was necessary and the results were within normal boiler operation guidelines. There was no report received from PWC Guam in the 1982 survey. However, in 1982, NAS, NAVSHIPREPAC, and NAVFAC Guam, reported generating 151,000 gal/yr of waste oils, consisting mainly of lube oils, with some fuel and hydraulic fluids. Most of it (99.8%) is sent to NSD Guam for recycling, while a small amount is used for firefighting training. The total waste oil generated could replace 22% of the total fuel oil consumption.

NAVSTA Guantanamo Bay, Cuba. In FY80 this activity reported burning about 180,000 gallons of waste oil a year in a combination desalination steam power plant. The waste oil consisted of used lube oil, hydraulic fluid, and contaminated fuel from transportation and maintenance service areas. The oil was collected and stored in a Ship Waste Offload Barge (SWOB). Future plans included the use of a Waste Oil Raft (DONUT) to aid in separation of water and solids from the oil. Transported to the plant, the waste oil was direct-blended into existing tankage with NSFO at a concentration of about 5% (typically 2,000 gallons in 40,000 gallons regular fuel) and burned at the normal rate. Analysis of the waste oil showed an average heating value of 135,000 Btu/gal. No major problems with burning were encountered. However, early problems included flameouts due to high water concentrations in the oil and clogging of burners and equipment by "globs" and sediment. Increased settling time prior to burning has greatly reduced operational problems. Unknown quantities of abandoned fuel found in oil underground storage tanks were also being salvaged and utilized as a supplemental fuel. In FY82 the station reported generating and burning 110,000 gallons of waste oils per year, which includes 90,000 gallons from ships and 20,000 gallons from shops. The waste oil resembles NSFO and is recycled and used in three 103,000-lb/hr and one 120,000-lb/hr boilers at power plant No. 4. The boilers are water tube with automatic control and are operated continuously, activated by flow. The total waste oil generated could replace 0.8% of the total fuel oil consumption.

Honolulu, Hawaii. The activities in this area generate and burn 1,470,000 gallons of waste oil annually. Bilge and defueling operations send the waste oils to a reclamation plant for water removal prior to burning. Diesel fuel fired fire tube boilers, ranging in size from 0.56 to 1.7 MBtu were used. The total waste oil generated is 15 times the total fuel oil consumption.

NAC Indianapolis, Ind. In FY80 this center reported burning approximately 5,000 gallons of waste oil in one of three 17,000-lb/hr steam boilers. The major source was machine shop cutting oil. Metal filings present in the oil were the major problem and were removed by a centrifuge prior to storing or burning. Used lube oil was the secondary source and was collected from 60 vehicles in the transportation department and from a collection center provided for individuals. The boilers are designed to burn natural gas as primary fuel and F05 as backup. Storage of F05 was maintained in six 1,500-gallon tanks, one of which was set aside to receive waste oil. Clean F05 and waste oil were mixed at about a 50/50 ratio in this tank prior to burning. Problems of increased smoke emission and clogged filters due to dirt and sediment suspended in the waste oil were sometimes experienced. In FY82, they reported generating and burning 2,692 gallons of waste oil per year (to get this, they averaged quantities for 1979, 1980, 1981) in three of five boilers: two water tube and one fire tube gas or oil fired types. The fire tube boiler is rated at 500 hp, has mechanical atomization, and operates intermittently. The waste oil is lube oil from shops and "used motor oil brought in by employees." The total waste oil generated could replace 19% of the total fuel oil consumption.

Kaneohe Bay, Hawaii. This area generates 924,000 gallons of waste oil annually. An estimated 10% of this waste oil is contaminated JP-5 and is being burned in boilers. The waste oil is treated at the reclamation facility. Two 300-MBtu/hr fire tube boilers operating intermittently with air atomizing burners were used. The total waste oil generated equals 1.7 times the total fuel oil consumption.

Keflavik, Iceland. This area generates 20,000 gallons of waste oil annually consisting of used lube oil, contaminated JP-4, diesel, and fuels from aircraft defueling operations. About half of this is burned at 10% waste oil concentration. Minor problems have occurred when JP-4 is excessively contaminated. The total waste oil generated could replace 0.3% of the total fuel oil consumption.

NAVSTA Mayport, Fla. This station burned 650,000 gallons of waste oil during FY80, 750,000 gallons during FY79, and 500,000 gallons during FY78. The major source is ship discharge, which consists of very dirty DFM (greater than 90%), water, and sediment. For treatment of the waste oil, the ship discharge was placed in series of three 157,500-gallon tanks, allowed to settle, and water drained off the bottom each time. The third time it was allowed to settle for 24 hours. The top 4 to 5 feet of oil was skimmed off the tank and trucked to the boiler plant. The three 33,500-lb/hr water tube boilers are designed to burn F05. The waste oil, which resembles basically F02, blends in well with the regular

fuel and has an estimated heating value of 140,000 Btu/gal, which closely approximates that of DFM. Samples of the waste oil burned are periodically taken and analyzed.

Maintenance and operational problems include:

- Pumps - rotary vane pumps used for fuel transport were especially intolerant to solids. Damage included scored liners and pitted vanes.
- Strainers - strainers required cleaning up to four times as often when using waste oil.
- Burner tips - deformation of burner tip orifices increased. The orifices became enlarged, elongated, and pitted.

Removal of water and especially solids from the waste oil prior to burning is important in reducing maintenance and repair of boiler equipment.

In FY82, the activity reported generating and burning 400,000 gallons of waste oil annually, consisting of contaminated DFM and lubricants. The oil was mixed with F05 (light) and burned in five water tube boilers with mechanical steam CDL atomizers and Todd "V" register, operated in continuous mode: three at 35,000 lb/hr and two at 30,000 lb/hr. Boiler plant operators have complained about abnormal maintenance caused by excessive contaminants. Sand, lead, and sodium chloride have impaired two pumps in 2 years, have coated furnace walls, and have created sand-blasting effects from atomizers. Packaged boilers make frequent cleanings impossible, though larger boilers are cleaned readily. Burner tip life has been shortened from 3 to 4 years to a 1-year maximum. Blending ratios ranging from 50/50 to 90/10 are used. Future plans include the installation of a 100 gal/hr centrifuge to remove water and sediment prior to burning. When this facility is completed, waste oil can be hauled or pumped directly to the boiler plant without lengthy settlement periods. The total waste oil generated could replace 16% of the total fuel oil consumption.

NAS Miramar, Calif. This air station reports 1,608,000 gallons of waste oil generated annually. An estimated 86% of this contaminated JP-5 and ship bilge is being burned. Boilers with a capacity of 38 MBtu/hr are water tube type and operate in continuous mode. Routine maintenance is slightly increased. Fireside deposits and residue plugging nozzles and strainers caused an increase in the changing or cleaning of these items. FOR from the Point Loma treatment facility is also burned. The total waste oil generated is 1.1 times the total fuel oil consumption.

Newport, R.I. This area generates a calculated 19,800 gallons of contaminated JP-5 and used lube oil annually. About 94% of this oil is burned in boilers. Boilers are both water tube and fire tube and range in size up to 110,000 lb/hr. Operating modes are both continuous and intermittent. From 50,000 to 75,000 gallons of oily waste (75% water and contaminants) are placed in storage tanks and allowed to settle out.

The waste oil extracted is then tested and blended with NSFO in a power house tank. The total waste oil generated could replace 0.3% of the total fuel oil consumption.

PWC Norfolk, Va. In FY80, PWC Norfolk utilized two different sources of supplemental fuel. The major source (4 million gal/yr) was the FOR obtained from Craney Island and burned independently in a separate burner with little or no operational changes required. Although existing FO6 pumps will handle the lighter weight FOR, they were being replaced with pumps designed specifically to handle fuel of FO2 consistency when ordinary wear and service life dictates. This activity has been burning FOR since 1979 with no problems or deviations from normal boiler operation. The secondary source of waste oil was used lube oil and hydraulic fluid that never amounts to more than 10,000 gal/yr. This waste oil was collected from the motor pool and service areas and transported to the boiler plant where it was direct-blended into existing FO6 tankage and burned along with the regular fuel. Prior to burning, waste oil and FOR are tested for specification compliance.

In FY82 PWC, NAVSTA, NAS, and FTC, Sewells Point, Norfolk, generated a total of 128,095 gallons of waste oils, consisting mainly of JP-5, lube, DFM, FO2, hydraulic fluids, and solvents. These come from ships, oil spills, shops, and aircraft areas. Of this quantity, 10,000 gallons are burned, a small amount is used for firefighting training, and some is sold, but the most part goes to the reclamation facility at Craney Island. Along with the 10,000 gallons burned, a larger quantity (2,655,000 gallons) of FOR received from Craney Island is also burned by PWC in two water wall, 60,000 lb/hr boilers with Peabody steam atomizers, one on line continuously, with a 75% load factor. These waste oils are blended with NSFO prior to burning. The total waste oil generated (aside from that obtained from Craney Island) could replace 0.4% of the total fuel oil consumption.

NAS Oceana, Va. This station operates four boilers totaling 210,000 lb/hr, all of which periodically burn FOR obtained from Craney Island. FOR is placed in the main tanks in the same manner as regular fuel and burned at a 50% concentration with FO6. No handling differences from that of regular fuel are experienced. However, the Btu rating of the FOR (135,000 to 140,000 Btu/gal) is lower than that of FO6; as a result, an increase in the firing rate is required to offset the deficit. In FY82, the station reported having generated 4,310 gallons of waste oil in 1981. This included lube, hydraulic fluids, and solvents. They reported also that in 1981, 952,000 gallons of FOR from the reclamation facility at Craney Island was burned as boiler fuel, blended 26% with 74% FO6. The total waste oil generated (aside from that obtained from Craney Island) could replace 0.1% of the total fuel oil consumption.

Pearl Harbor, Hawaii. This area reports 1,730,884 gallons of waste oil generated annually. An estimated 79% of this - mostly FOR, ship bilge, and used transformer oils* - is burned. Boilers are both water tube and fire tube. The largest three boilers are 40,000 lb/hr, steam atomized burners, with pneumatic controls. At least one of these three boilers is operating in a continuous mode at all times. Waste oils are

*PCB's are forwarded to DPDO for proper disposal.

sent to the NSC reclamation plant prior to burning. Downgraded DFM is blended at a 1:9 ratio with primary fuel oil and burned. The total waste oil generated could replace 57% of the total fuel oil consumption.

Puget Sound, Wash. This area generates 423,340 gallons of waste oil annually. An estimated 0.8% of this used lube oil, gasoline, and solvents is being burned in boilers by blending into F06. The total waste oil generated could supply 1.9 times the total fuel oil requirements.

Quantico, Va. This area generates 5,000 gallons of waste oil annually. An estimated 96% of this used JP-4 and crankcase oils is being burned in boilers. The boilers reported were water tubes, ranging in size from 0.2 to 20 MBtu/hr. The contaminated JP-4 is blended with the primary boiler fuel and burned at irregular intervals. The total waste oil generated could replace 0.1% of the total fuel oil consumption.

NAVSTA and NAVCOMMSTA, Rota, Spain. These activities reported burning approximately 201,000 gallons of contaminated fuel during FY82 in two 85,000-lb/hr boilers that normally burn F06. In FY80 the amount was 115,000 gallons. The sources of this oil are fuel pier spillage and fuel/water pumped from fuel tankers during tank cleaning. The fuel pier is equipped with spillage drains and holding tanks. Fuel spilled during unloading operations is collected and stored. Contaminated fuel unloaded from ships, and oils from shop operations, are placed in holding tanks. The fuel mixture is then transferred to an API separator for gravity separation and then into either low or high flashpoint tanks (the flashpoint is checked by a chemist). When the power plant calls for it, the fuel is transferred first to a direct blending tank and then pumped into a plant tank where it is held for 72 hours before burning at a concentration of 5% to 10%. Few or no adverse effects of use have been identified. The total waste oil generated could replace 3% of the total fuel oil consumption.

Washington, D.C. This area generates 3,500 gallons of used lube oil from automotive shops annually. An estimated 63% of this is burned in two 85,000-lb/hr water tube boilers. Primary fuels are F06 and DF2, and the operating mode is continuous with steam atomizing high-pressure burner nozzles. A separation system removes excessive contaminants. The waste oil fuel line is tapped into the fuel oil feed line and provides a 1:10 blending ratio. The total waste oil generated is less than 0.1% by volume of the total fuel oil consumption.

NAS Whidbey Island, Wash. In FY80, this activity reported collecting and burning approximately 60,000 gallons of waste oil and contaminated fuel. The waste oil burned consisted of a wide range of solvents, phenols, JP-5, hydraulic fluids, and used lube oils. Enlisted personnel collected fuel, solvents, and used lube oil from the flight line in mobile bowzers (700- to 1,000-gallon capacity) and transported it to the boiler plant, where it was stored in a 25,000-gallon underground tank. This oil was not treated. Secondly, Public Works collected used lube oil from garages, service areas, and other locations throughout the base and placed it in

a 5,000-gallon tank to settle. The oil that rises is skimmed off the top and placed in a 3,000-gallon second tank to settle, and water is drained off the bottom periodically. After settling, this oil was transported to the underground tank at the boiler plant. The waste oil was burned in one of three 44-MBtu/hr boilers which use natural gas as the primary fuel and FO2 as backup. No modifications to the burner itself were required. The waste oil was pumped from the underground holding tank through a fine strainer and into the burner. While the waste oil was burned, adjustments of the natural gas burners were made to compensate for fluctuations of the waste oil burner. Increased boiler cleaning efforts have been observed. The boiler utilizing waste oil has increased ash accumulation and requires cleaning twice a year. Boilers burning regular oil may be cleaned only every year or two. In FY82 NAS Whidbey reported generating 180,000 gallons of waste oil per year. Oily water goes to Manchester Naval Fuel Depot. Low flashpoint oils go to the firefighting school. Waste oils and JP-5 fuel are burned in one of three boilers at a rate of 7,500 gal/mo for 3 months of the year, totaling 22,500 gal/yr. This boiler was modified to accept waste oil as a fuel. It is a Coen style "MW" No. 2 mechanical atomizing boiler which burns natural gas, FO2, and intermittently waste oil. It has Fireye nonself-checking combustion controls and a capacity of 50,000 lb/hr, continuous operation. Natural gas is used to preheat this boiler for burning waste oil. The total waste oil generated could replace 54% of the total fuel oil consumption.

PWC Yokosuka, Japan. This PWC reported in FY80 that it was burning approximately 2,000 gal/yr of used lube oil from the transportation shop and transformer oil not containing PCB. The waste oil burned was only that generated and collected by PWC. This waste oil was collected in 55-gallon drums and poured through a fine screen filter into a 1,000-gallon tank where it settled. The oil was then burned straight (at 100% concentration) in a boiler specified for the purpose. By FY82 the quantity of waste oil burned had increased to 12,000 gal/yr and consisted of used lube and fuel oils from the power plant, boiler plant, and transportation shop. After solvents are removed, the oil is blended in appropriate portions and burned in water tube and fire tube boilers. The total capacity of 22 boilers is 574 MBtu/hr. These are automatic steam/air and rotary cup atomization burners burning low sulphur fuel oil and DFM. They are operated continuously at a 76% load in winter and a 68% load in summer. Although PWC, NAVSHIPREPFAC, and NAVCOMMSTA generate about 145,000 gallons of waste oils per year, the waste oil burned is still only that generated and collected by PWC. Ship bilge waste oil generated dockside is collected in DONUTS and SWOB barges and transported to the Naval Supply Depot, where the waste oil goes through gravity separation and is blended into FO6 and sold. The total waste oil generated could replace 1% of the total fuel oil consumption.

Tabulated Results of Survey

Table 5 provides an overview of pertinent experience, listed by activity. Table 6 summarizes the energy usage and waste oil generation and distribution by these activities grouped into 153 locations and

totalled by Naval district. A more detailed breakdown by locations within each Naval district is presented in Table 3, A through L and includes alphabetical listings of the locations surveyed, with energy usage and waste oil generation and distribution data.

Table 6 shows that 19 million gallons of waste oil were generated.* Of this quantity, 57% was burned as boiler fuel, and 43% was distributed in several ways (see footnote e of Table 3). Table 3 also shows that 20% of the locations surveyed burned waste oil as boiler fuel. Furthermore, not all of the locations surveyed indicated waste oil generation.** The data show that 26% of those who reported having generated waste oil had burned it as boiler fuel. An overall observation is that there is a potential for more productive use of significant quantities of waste oil.

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$*(2,607,785 \text{ MBtu}) / (0.1357 \text{ MBtu/gal}) = 19 \text{ million gallons.}$

**Some contacted were reluctant to report the quantity of waste oil generated.

DEFINITIONS

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CHIL LIST	Consolidated Hazardous Item List (Ref 5)
Contaminated Fuel	Fuel that has been contaminated by foreign material such as water, sediment, other fuels, oil, and solvents, and cannot be used for its intended purpose.
DEIS	Defense Energy Information Service
DF, DF2, DFM	Diesel Fuel, Diesel Fuel #2, Diesel Fuel Marine
DLA	Defense Logistics Agency
DONUT	Waste oil raft that performs initial gravity separation
DPDO	Defense Property Disposal Office
ECIP	Energy Conservation Investment Program (Ref 4)
FO, FO2, FO5, FO6	Fuel Oil, Fuel Oil No. 2, Fuel Oil No. 5, Fuel Oil No. 6
FOR	Fuel Oil Reclaimed. Oil that has been processed by a Naval Supply activity through a low-temperature heating and settling facility to remove suspended water and sediment. It is then usually reissued or blended into other fuel.
NAVFAC	Naval Facilities Engineering Command
NAVSUP	Naval Supply Systems Command
NEESA	Naval Energy and Environmental Support Activity (Port Hueneme, Calif.)
NSFO	Navy Special Fuel Oil
SUS	Saybolt Universal Seconds (a measure of viscosity)
SWOB	Ship Waste Offload Barge
UIC	Unit Identification Code
Waste Oil	The descriptive term applied to used or contaminated petroleum-based and synthetic/chemical-based oil products that are no longer suitable for use as originally intended.

Table 1. Oil Product Types

Type	Characteristics ^a	Product Examples
A - Gasolines and solvents	Hazardous, very low flashpoint	Automotive gasoline Aviation gasoline JP-4
B - Kerosenes	Clean burning light fuel, low flashpoint (100°F minimum), less volatile than gasolines	F01 JP-5
C - Diesel Fuels	Flashpoint 100°F minimum, slightly viscous	F02 Marine diesel Automotive diesel
D - Other Fuel Oils	No. 4-Moderately viscous, odoriferous, flashpoint 130°F minimum No. 5-Viscous, odoriferous, flashpoint 130°F minimum No. 6-"Black oil," very viscous, odoriferous, flashpoint 140°F minimum	F04 through F06
E - Petroleum-Based Oils	Generally high flashpoint, viscous fluid or semisolid greases	Lubricating oils/greases Hydraulic fluids Transmission fluids
F - Synthetic/Chemical-Based Oils and Halogenated Solvents	Similar to petroleum-based oils but may contain halogens, combustion products may be toxic and hazardous	Lubricating oils/greases Hydraulic fluids Brake fluids

^aFlashpoint values taken from ASTM D-396, Standard Specification for Fuel Oils (App B).

Table 2. Estimated Annual Energy Consumption by Naval Shore Facilities

Type of Energy Used	Energy Consumption ^a	
	10 ⁶ MBtu	Total (%)
GLO		
Natural gas	28	15
Liquid petroleum gases	0.6	<1
Fuel oils	43	24
Electricity	104	57
Coal	3	2
Steam and hot water	2	1
Total	181	100

^aFigures are illustrative only; 1 MBtu \approx 7.37 gallons light fuel oil.

Table 3. Energy Usage and Waste Oil Generation and Usage, by Locations Surveyed^a

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d						Composition	
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)	Generated (MBtu)	Disposal Methods ^e	Ratios (%)		Source			
							All Fuel/All Energy	Fuel Oil/All Fuel		Burned/Generated		Generated/Fuel Oil Used
Part A. Naval District Four												
Bloomfield, CT (1)	93,933	24,147	24,147	25.7	100	326	D	0	0.4	automotive	lube	
Brooklyn, NY (2)	372,055	149,314	86,436	40.1	57.9	1,166	B	14	0.3	aircraft	JP-5	
Brunswick, ME (2)	651,084	345,401	345,401	53.1	100	1,018	B	0	0.4	generators	lube	
Cutler, ME (2)	329,615	273,413	273,391	82.9	100	580	B	0	1.7	shops	lube	
Danville, RI (2)	112,711	56,219	33,240	49.9	59.1	7,192	B	0	4.7	automotive	lube	
Earle, NJ (3)	314,435	152,696	151,722	48.6	99.4	86.6	--	--	--	--	--	
Garden City, NY (1)	32,289	6,714	5,612	20.8	0	3,694	A,B	--	0.8	aircraft, auto	JP-5, lube	
Lakehurst, NJ (3)	742,731	469,377	459,136	63.2	97.8	733	D	0	0.3	shops	lube	
Mechanicsburg, PA (1)	841,391	276,761	255,543	32.9	92.3	24,433	B	0	1.7	ships, shops	lube, DPM, F06	
New London, CT (1)	2,866,707	1,480,519	1,479,982	51.6	100	2,694	B	94	0.3	ships	JP-5, DPM	
Newport, RI (7)	2,102,949	1,185,029	1,026,344	56.4	86.6	10,335	B,D	0	0.9	ships	bilge, lube	
Philadelphia, PA (13)	5,138,029	3,683,836	1,096,982	71.7	29.8	13,570	E	0	1.0	ships	bilge, lube	
Pittsfield, MA (1)	431,272	115,392	61,397	26.8	53.2	14	D	0	0.3	automotive	lube	
Portsmouth, NH (4)	1,689,445	1,379,986	1,379,986	81.7	100	14	D	0	0.05	automotive	lube	
Ravenna, OH (1)	75,519	45,343	4,234	60.0	9.3	1,086	D	0	1.1	aircraft, shops	F06, lube, solvents	
Scotia, NY (1)	60,539	36,225	30,375	59.8	63.9	679	B	0	0.5	auto, aircraft	lube	
South Weymouth, MA (1)	164,315	97,070	97,070	59.1	100	366	D	0	1.2	auto, aircraft	lube	
Warminster, PA (2)	474,633	171,664	141,126	36.2	62.2	163	B	0	0.4	aircraft	lube	
Willow Grove, PA (2)	327,038	171,761	29,552	52.5	17.2	68,033	--	4	1.0	automotive	lube	
Winter Harbor, ME (2)	114,405	37,822	37,822	33.1	100							
Total (52)	16,935,096	10,158,689	7,019,698	60.0	69.1							
Part B. Naval District Five												
Camp Elmore, VA (1)	57,763	41,836	38,542	72.4	92.1	1,493	D	0	3.9	automotive	lube	
Camp Lejeune, NC (2)	4,970,742	2,553,592	2,287,538	51.4	89.6	13,570	B	--	0.6	automotive	lube	
Chesapeake, VA (3)	187,536	30,471	30,146	16.2	98.9	27	D	0	0.1	shops	lube	
Dahlgren, VA (3)	913,312	285,160	282,020	31.2	98.9	4,071	B,D	0	1.4	ships, shops	lube, bilge, solvents	
Little Creek, VA (3)	1,972,310	1,049,158	968,641	53.2	92.3	46,898	B	0	4.8	ships, shops	JP-5, DPM, lube	
Norfolk, VA (19)	11,044,511	4,802,791	4,283,132	43.5	89.2	17,380	D	2,100 ^f	0.4	ships	JP-5, DPM, lube	
Oceans, VA (2)	1,455,340	642,934	531,342	44.2	82.6	585	A	22,000 ^f	0.1	shops	lube, solvents	
Portsmouth, VA (4)	4,343,776	2,530,120	2,491,840	56.2	90.6	145,878	D	0	6.4	ships, shops	DPM, bilge, solvents	

continued

Table 3. Continued

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d						
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)		Generated (MBtu)	Disposal Methods	Ratios (%)		Source	Composition
				All Fuel/All Energy	Fuel Oil/All Fuel			Burned/Generated	Generated/Fuel Oil Used		
Part B. Naval District Five (continued)											
Quantico, VA (1)	1,952,256	1,166,101	702,965	59.7	60.3	679	A	96	0.1	aircraft	JP-5, lube
Sugar Grove, WV (2)	30,672	11,114	2,275	36.2	20.5	20	A	0	0.9	automotive	lube
Thurmont, MD (2)	82,369	19,695	19,695	23.9	100						
Virginia Beach, VA (4)	927,658	374,292	376,268	40.3	100	430	B	0	0.1	shops	kerosene, lube
Forktown, VA (2)	651,896	345,239	345,239	52.5	100						
Total (48)	28,591,140	13,852,603	12,159,643	48.5	87.8	231,031	--	214 ^f	1.9		
Part C. Naval District Six											
Albany, GA (1)	880,661	269,051	7,527	30.6	2.8	4,478	B	0	59	shops	lube
Athens, GA (1)	70,915	24,666	3,518	34.8	14.3	0	--	--	--	aircraft	lube
Atlanta, GA (1)	71,182	24,852	2,252	34.9	9.1	679	B,D	0	30	shops	lube, solvents
Beaufort, SC (3)	1,035,879	312,433	105,099	30.2	33.6	2,069		0	2.0		
Cecil Field, FL (2)	791,390	221,981	24,866	28.1	11.2	10,856	A,B	0	44	aircraft	JP-5, lube
Charleston, SC (14)	5,046,195	1,690,447	767,563	33.5	45.4	175,340	E,D,C	20	23	ships, shops	bilge, lube
Cherry Point, NC (2)	2,991,173	1,513,322	1,224,323	50.6	80.9	46,003	A,B	0	3.8	aircraft, automotive	JP-5, lube
Gulftport, MS (1)	331,940	94,546	64	28.5	0.1	1,954	B	0	3,100	shops	lube
Homestead, FL (1)	42,737	1,429	1,420	3.3	99.4	37	D	0	2.6	aircraft, automotive	lube
Jacksonville, FL (5)	2,417,704	958,068	13,540	39.6	1.4	25,498	A,B	0	190	aircraft, shops	JP-5, lube
Key West, FL (2)	491,093	25,179	25,069	5.1	99.6	388	B	0	1.5	aircraft, automotive	lube
Mayport, FL (3)	1,660,248	340,214	339,130	20.5	99.7	54,280	--	340 ^f	16	ships	bilge, lube
Memphis, TN (4)	1,910,265	1,003,196	77,110	52.5	7.7	1,160	D	0	1.5	aircraft, automotive	lube
Orlando, FL (2)	1,094,753	199,790	20,244	18.3	10.1	1,251	B	0	6.2	aircraft, automotive	lube
Panama City, FL (2)	152,129	14,751	14,596	9.7	98.9	2,036	D	0	14	ships, shops, aircraft	bilge, lube
Parrish Island, SC (1)	1,196,660	865,504	74,481	71.5	8.7	679	B	0	0.9	shops, automotive	lube, solvents
Pensacola, FL (8)	3,984,249	2,487,337	41,053	62.4	1.7	8,142	D	0	19.8	auto, shops, aircraft	lube, solvents
Sausley Field, FL (1)	32,057	19,135	1,967	59.7	8.9	0	--	--	--		
Total (56)	24,201,230	10,055,901	2,743,802	41.6	27.3	334,850		65	12		

continued

Table 3. Continued

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d							
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)		Generated (MBtu)	Disposal Methods	Ratios (%)		Source	Composition	
				All Fuel/ All Energy	Fuel Oil/ All Fuel			Burned/ Generated	Generated/ Fuel Oil Used			
Part D. Naval District Eight												
Dallas, TX (1)	259,201	69,205	5,846	26.7	8.4	380	B	0	6.5	aircraft, automotive	JP-4, lube	
Driver, AR (1)	152,562	1,402	1,402	0.9	100							
New Orleans, LA (3)	89,851	36,897	11,353	41.1	30.8	54	D	0	0.5	automotive	lube	
Total (5)	501,614	107,504	18,601	21.4	17.3	434	--	0	2.3			
Part E. Naval District Nine												
Crane, IN (3)	956,667	477,123	473,044	49.8	99.1	1,305	B	23	0.3	shops	lube	
Great Lakes, IL (3)	3,139,267	2,263,908	21,008	72.1	0.9	305	B	0	1.5	automotive	lube	
Indianapolis, IN (1)	1,386,712	86,108	1,890	6.2	2.2	365	--	100	19	shops	lube	
Minneapolis, MN (3)	1,159,117	427,343	202,994	36.9	47.5							
Olathe, KS (2)	47,258	27,839	8,709	58.9	31.3	0	--	--	--			
Total (12)	6,689,021	3,282,321	707,645	49.1	21.6	1,975	--	34	0.3			
Part F. Naval District Eleven												
Alameda, CA (4)	2,239,395	995,978	281,487	44.5	28.3	22,610	A,B	0	8.0	ships, aircraft, shops	bilge, lube solvents	
Barstow, CA (1)	617,608	316,310	88,869	51.2	28.1	22,798	B	0	26	automotive	lube	
Camp Pendleton, CA (1)	2,682,556	1,240,502	234,616	46.2	18.9	13,027	B	480	5.6	shops, FOR, ships	lube, FO	
Centerville Beach, CA (1)	68,855	28,969	28,969	42.1	100	0	--	--	--			
China Lake, CA (2)	1,561,849	639,412	69,262	40.9	10.8	5,428	A	75	7.8	aircraft, automotive	JP-4, JP-5, lube	
Concord, CA (2)	260,591	98,783	54,363	37.9	55.0	1,357	B,D	0	--	shops	lube	
Coronado, CA (1)	290,862	110,552	514	38.0	0.5	14,113	E	0	2,700	ships	bilge	
E1 Centro, CA (1)	129,530	10,038	2,160	7.8	21.5	109	A,B	0	5.0	aircraft	JP-5	
El Toro, CA (1)	1,032,293	318,464	38,936	30.9	12.2	26,462	A	75	68	aircraft	JP-5	
Fallon, NV (2)	319,801	161,403	128,310	50.5	79.5	8,077	A,C	74	6.3	aircraft, shops	JP-5, lube	
Lemoore, CA (2)	908,407	347,906	47,387	38.3	13.6	2,714	B	0	5.7	aircraft, shops	JP-5, lube	
Long Beach, CA (4)	2,180,322	743,755	3,196	34.1	0.4	293,381	B	0	9,200	ships, shops	bilge, lube	
Mare Island, CA (4)	2,435,690	1,002,648	146,544	41.2	14.6	0	--	--	--			
Miramar, CA (2)	927,441	325,335	207,371	35.1	63.7	218,206	A	86	105	aircraft	JP-4, JP-5	
Moffett Field, CA (2)	661,958	269,820	11,011	40.8	4.1	8,142	A,B	0	74	aircraft, automotive	lube	
Monterey, CA (2)	342,082	125,730	1,053	36.8	0.8	0	--	--	--			
North Island, CA (1)	892,494	65,795	4,540	7.4	6.9	19,039	A,D	0	420	aircraft, shops	JP-5, AV gas, lube	

continued

Table 3. Continued

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d						Composition
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)		Generated (MBtu)	Disposal Methods	Ratios (%)		Source	
				All Energy	Fuel Oil/All Fuel			Burned/Generated	Generated/Fuel Oil Used		
Part F. Naval District Eleven (continued)											
Oakland, CA (3)	434,885	144,062	49,234	33.1	34.2	113,988	B	0	230	0	ships, automotive
Pasadena, CA (1)	1,294	250	39	19.3	15.6	0	--	--	--	--	ships, automotive
Point Loma, CA (1)	474,787	34,254	4,581	7.2	13.4	113,988	B	0	2,500	0	ships, automotive
Point Mugu, CA (1)	945,566	261,630	119,978	27.7	45.9	3,800	A	0	3.2	0	JP-5, lube
Point Sur, CA (2)	28,681	13,740	11,575	47.9	84.2	7	D	0	0.1	0	lube
Port Hueneme, CA (5)	645,526	231,023	21,232	35.8	9.2	4,750	B	0	22	0	ships
San Bruno, CA (1)	33,898	9,434	286	27.8	3.0	0	--	--	--	--	ships
San Diego, CA (13)	6,859,028	752,800	37,450	11.0	5.0	254,021	D	0	680	0	ships
San Francisco, CA (1)	41,240	5,640	113	13.7	2.0	0	--	--	--	--	bilge, DFM
Seal Beach, CA (2)	245,563	50,335	2,180	20.5	4.3	679	B,D	0	31	0	shops
Skaggs Island, CA (1)	101,660	25,216	1,461	24.8	5.0	27	--	--	2.1	0	shops
Stockton, CA (1)	374,562	40,807	41	10.9	0.1	136	D	0	330	0	shops
Treasure Island, CA (1)	17,101	7,995	1,087	46.8	13.6	0	--	--	--	--	lube
29 Palms, CA (1)	901,203	372,885	187,597	41.4	50.3	18,998	A,B	0	10	0	lube
Utah (1)	237,936	185,655	26,254	78.9	14.1	0	--	--	--	--	JP-5, solvents
Yuma, AZ (1)	584,694	97,042	1,019	16.6	1.1	2,720	A	0	260	0	shops
Total (69)	35,087,772	18,034,168	1,812,526	51.4	10.1	1,168,577	--	24	58.0	--	--
Part G. Naval District Thirteen											
Adak, AK (3)	1,101,336	1,101,336	1,101,336	100	100	3,528	A	96	0.3	0	JP-5, lube
Bangor, WA (2)	1,295,776	359,709	70,407	27.8	19.6	21,169	--	100	30	0	F02, lube, DF
Barrow, AK (1)	353,723	353,723	353,723	100	100	0	--	--	--	--	lube
Bremerton, WA (4)	3,137,141	1,434,840	1,326,384	45.7	92.4	163	D	0	3.9	0	generators, automotive
Coos Head, OR (1)	19,329	4,179	4,179	21.6	100	6,785	D,B	0	1.7	0	ships, shops
Jim Creek, WA (1)	133,977	2,073	1,345	1.5	64.9	49	D	0	0.4	0	lube
Keyport, WA (3)	1,170,714	391,341	387,826	33.4	99.1	57,447	B,D	0.8	190	0	gasoline
Manchester, WA (1)	29,339	20,395	20,395	69.5	100	574	D	0	0.6	0	lube, bilge
Pacific Beach, WA (1)	28,438	12,036	12,036	42.3	100	24,426	A	13	54	0	ships
Puget Sound, WA (2)	143,091	30,767	30,767	21.5	100	114,141	--	25	3.3	--	aircraft
Seattle, WA (4)	427,642	201,358	98,494	47.1	48.9						
Whidbey Island, WA (4)	1,226,042	433,716	45,304	35.4	10.4						
Total (27)	9,066,548	4,345,173	3,451,896	47.9	79.4						

continued

Table 3. Continued

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d						
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)		Generated (MBtu)	Disposal Methods ^e	Ratios (%)		Source	Composition
				All Fuel/ All Energy	Fuel Oil/ All Fuel			Burned/ Generated	Generated/ Fuel Oil Used		
Part H. Naval District Fourteen											
Barbers Point, HI (2)	270,482	22,729	22,297	8.4	98.1	6,785	D	0	30	diesel engines	DPM
Barking Sands, HI (1)	104,932	10,090	10,090	9.6	100	841	A	96	8.3	shops	lube
Camp H. M. Smith, HI (1)	135,916	17,376	17,123	12.8	98.5	14	B	0	0.1	shops	lube
Honolulu, HI (1)	597,845	13,727	13,727	2.3	100	199,479	--	100	1,500	ships	blige, lube
Kaneohe Bay, HI (1)	926,867	74,151	72,002	8.0	97.1	125,387	D	9.9	170	aircraft	JP-5, lube
Lualualei, HI (1)	122,230	9,246	9,246	7.6	100	28	D	0	0.3	automotive generators	lube
Midway Islands (2)	148,287	148,287	148,287	100	100	333	A, D	0	0.1	generators	lube
Pearl Harbor, HI (7)	3,172,928	441,464	409,965	13.9	92.9	234,881	A, B	79	57	ships	blige
Total (16)	5,479,487	737,070	702,737	13.5	95.3	567,748		70	81		
Part I. Naval District Twenty-One											
Alleghany Ballistic Laboratory, MD (1)	567,929	265,169	265,169	46.7	100		--	--	--	gear boxes	lube
Annapolis, MD (5)	1,485,824	695,679	75,902	46.8	10.9	0	B	2	0.1	auto, shops	lube
Bethesda, MD (2)	1,695,624	573,220	573,220	33.8	100	757	B	0	0.1	shops	lube
Indian Head, MD (4)	1,588,869	1,473,368	1,473,368	92.7	100	951					
Patuxent River, MD (4)	1,478,949	652,601	650,194	44.1	99.6	4,071	A, B	0	0.6	aircraft, shops	lube, solvents
Washington, DC (13)	3,633,509	1,706,645	1,658,093	47.0	97.2	475	B	63	0.1	shops	lube
Total (29)	10,450,704	5,366,682	4,695,946	51.4	87.5	6,254		5	0.1		
Part J. Naval District Thirty											
Andros Island, Bahamas (1)	218,693	218,693	218,693	100	100	489	A	50	0.2	generators	lube
Antigua, West Indies (1)	21,101	5,383	5,383	25.5	100	27	A, C	0	0.5	automotive shops	lube
Argentina, Newfoundland (2)	275,503	167,240	167,240	60.7	100	244	D	0	0.1	compressors	lube
Bermuda (3)	409,186	324,112	321,424	79.2	99.2	163	F	0	0.1		
Canal Zone (1)	101,963	393	393	0.4	100						
Eleuthera, Bahamas (2)	14,065	14,065	14,065	100	100						
Grand Turk, West Indies (1)	11,622	11,622	11,622	100	100						
Guantanamo, Cuba (6)	1,944,993	1,944,993	1,944,993	100	100	14,927	--	100	0.8	ships, shops	blige
Keflavik, Iceland (4)	1,502,247	954,970	954,970	63.6	100	2,714	A	50	0.3	aircraft	lube, JP-4, DF
Ponce, Puerto Rico (1)	186,434	3,108	3,108	1.7	100	68	B	0	2.2	generators	lube
Roosevelt Roads, PR (2)	631,908	27,676	26,762	4.4	96.7						
Sabana, Puerto Rico (1)	81,756	3,885	3,885	4.8	100	204	D	0	5.3	automotive	lube
Total (25)	5,399,471	3,676,140	3,672,538	68.1	99.9	18,836	--	88	0.5	--	--

continued

Table 3. Continued

Location Surveyed ^b	Energy Usage ^c				Waste Oil Distribution ^d					Composition
	All Types of Energy (Mbtu)	All Types of Fuel (Mbtu)	Fuel Oil (Mbtu)	Ratios (%)	Generated (Mbtu)	Disposal Methods	Ratios (%)		Source	
							Burned/Generated	Generated/Fuel Oil Used		
Part K. Naval District Thirty-One										
Breedy, UK (1)	81,546	34,369	34,369	42.1	100	556	0	1.6	generators shops	lube
Edzell, UK (2)	238,850	88,947	87,959	37.2	98.9	27	0	0.1		lube
Holy Loch, UK (1)	33,987	12,829	9,366	37.7	73.0		0	28	generators	lube
La Maddalena, Italy (2)	21,041	3,243	2,875	15.4	88.7	814	0	0.1	generators auto,	lube
London, England (1)	100,446	19,200	18,663	19.1	97.2	7	0		generators automotive	lube
Naples, Italy (4)	351,759	69,323	66,641	19.7	96.1	560	0	0.8		lube
Nea Marki, Greece (1)	185,423	174,020	174,020	93.9	100		99	3.2	shops,	lube, fuel
Rota, Spain (4)	972,323	858,944	858,944	88.3	100	27,519	B		generators	
Sigonella, Italy (2)	495,506	76,428	75,907	15.4	99.3	0	--	--	auto,	lube
Souda Bay, Greece (1)	20,317	4,808	4,808	23.7	100	136	0	2.8	shops	lube
Thurso, UK (2)	120,862	15,233	15,233	12.6	100	45	0	0.3	automotive	lube
Total (21)	2,622,060	1,357,344	1,348,785	51.8	99.4	29,664	92	2.2	--	--
Part L. Naval District Forty										
Atsugi, Japan (2)	606,546	355,151	355,151	58.6	100	1,254	0	0.4	shops	lube
Camp S. D. Butler, Japan (1)	2,139,146	508,812	508,480	23.8	99.9	8,142	17	1.6	aircraft, shops	F02, JP-4, lube
Qubi Point, Philippines (1)	516,319	136,349	136,349	26.4	100	7,353	0	5.4		
Diego Garcia (1)	287,483	287,483	287,483	100	100	20,530	99	22	shops,	fuel, lube
Guam (7)	1,745,462	92,311	92,311	5.3	100		0	0.1	generators shops,	F02, lube
Harold E. Holt, Australia (1)	462,119	462,119	462,119	100	100	679	0	3.2	generators	JP-5, JP-4
Iwakuni, Japan (1)	662,884	252,522	252,522	38.1	100	8,142	0	1.9	aircraft	lube
Korea (3)	35,562	8,036	8,036	22.6	100	149	0	0.6	automotive	
Okinawa, Japan (1)	61,393	22,104	22,104	36.0	100	136	0			
Sasebo, Japan (4)	157,940	56,510	53,383	35.8	94.5		0	0.1	auto,	lube, sludge
Subic Bay, Philippines (9)	3,460,020	1,318,528	1,318,528	38.1	100	180	8.3	1.0	settling tank	lube
Yokosuka, Japan (9)	3,287,070	1,897,795	1,897,795	57.7	100	19,677	35	1.2	--	--
Total (40)	13,421,944	5,397,720	5,394,261	40.2	99.9	66,242				

continued

Table 3. Continued

- ^a Data for only the surveyed locations where fuel oil was consumed as indicated in the FY80 DEIS II report. Therefore, the totals are not Navywide totals.
- ^b Figure in parentheses indicates number of activities surveyed at each location.
- ^c For FY80, based on Reference 4.
- ^d FY82 data, based on NCEL's waste oil generation/combustion experience survey, and represent responses from 94 of the 153 locations surveyed.
(One gallon waste oil = 0.1357 MBtu.)
- ^e Disposition method notation:
- | | | |
|--------------------------------|--|-----------------------------------|
| A. Local firefighting training | B. NAVSUP, DLA, or DEDO handles resale | C. Weed/dust control |
| D. Sell or give to haulers | E. Pay to haul away | F. Stored; no disposition planned |
- Unless otherwise stated, locations reported no major modifications or problems when burning waste oil. Information shown is for primary sources at respective locations.
- ^f Some shore facilities burn reclaimed oil received from the nearby reclamation facility (e.g., Craney Island, VA; Mayport, FL; North Island or Point Loma, CA).

Table 4. Properties of Some Oils Tested

Properties	Fuel Oil			Heavy Shale Oil	Used Lube Oil	Ship's Waste Oil	Contaminated JP-5
	No. 6	No. 5	No. 2				
API Gravity	23		34	22	26.1	29.1	40.6
Heating Value (HHV, Btu/lb)	19,150	18,576	19,560	18,420	19,270	19,390	19,770
Viscosity, SUS @ 100°F	324		35	150	527	60	31
Flashpoint, °F	245		168	295	370	260	145
Water and Sediment, %	0.12	0.44	<0.1	1.0	<0.1	0.12	3.4
Carbon Residue (Ramsbottom), %	3.44		0.12	2.0	1.11	0.17	0.10
Copper Strip Corrosion	S.T. ^a		S.T.		S.T.	S.T.	S.T.
Carbon, %	86.61	85.02	86.11	85.8	85.08	86.18	86.05
Hydrogen, %	12.25	11.53	12.94	11.19	13.13	13.13	13.43
Nitrogen, %	0.24	0.33	0.022	1.95	0.074	0.008	0.004
Sulfur, %	0.28	1.31	0.082	0.46	0.44	0.081	0.086
Ash, %	0.016	0.032	<0.001	0.007	1.36	0.001	0.001
Oxygen, % by Difference	0.60	1.78	0.85	0.59	0	0.60	0.43

^aS.T. = slight tarnish.

Table 5. Summary of Navy and Marine Corps Experience with Burning Waste Oil as a Supplemental Fuel

Location ^a	Waste Oil Burned			Blending Method	Comments ^b
	Quantity (gal.)		Type		
	FY80	FY82			
Adak, AK (13)	34,000	25,000	JP-5, lube	direct	Blended one part of lube into four parts of JP-5 and burned in base steam plant.
Andros Island, Bahamas (30)		1,800	lube	direct	Blended with diesel fuel oil.
Bangor, WA (13)		156,000	FO2, DF lube	direct	Treated at Manchester reclamation plant prior to burning.
Barking Sands, HI (14)		6,000	lube	in-line	Used lube oils run through a filter separator and mixed with DF2 at a 1:10 ratio. Excessive corrosion on feed lines before separator applied.
Bethesda, MD (21)		100	lube	direct	Blended with FO6 before burning.
Brunswick, ME (4)		1,200	JP-5	direct	Blended by dumping into FO6 storage tank.
Camp Pendleton, CA (11)		460,800	FOR, lube bilge	direct	FOR from Point Loma and waste oil directly from NAVSTA waterfront operations.
Camp S. D. Butler, Japan (40)		10,000	DF2, JP-4, NSFO, kerosene, lube	direct	Burning intermittently in dry back, marine, and locomotive type boilers at MCAS.
Charleston, SC (6)		258,000	bilge, lube	direct	Gravitation reclamation system used. Blended into Navy Special. \$1.2 million credited NAVSUP since FY80.
China Lake, CA (11)	30,000	30,000	JP-5, DF, lube	in-line	Used lube oils, JP-5 and DF were blended with FO6 and burned. No operational or emission difficulties were encountered.
Crane, IN (9)		2,200	lube	direct	Blended with FO6 before burning.
El Toro, CA (11)		146,300	lube, JP-5 kerosene	direct	54 water tube and fire tube gas/oil fired boilers with automatic controls and air atomization burners.
Fallon, NV (11)	2,400	44,000	JP-5, lube, hydraulic fluid.	direct	Waste oil (JP-5) dumped into the existing fuel tanks and burned straight.
Guam (40)	608,000		lube, DFM, FO	direct	Blended into regular fuel oil tank when half full.
Guantanamo, Cuba (30)	180,000	110,000	lube, hydraulic fluid, FO	direct	Blended with NSFO in existing tankage at about 5%. Waste oil allowed to settle, burned in 4 boilers. No major problems.
Honolulu, HI (14)		1,470,000	bilge, JP-5, lube	direct	Reclamation facility removes excessive water, blended with NSFO.

continued

Table 5. Continued

Location ^a	Waste Oil Burned			Blending Method	Comments ^b
	Quantity (gal)		Type		
	FY80	FY82			
Indianapolis, IN (9)	5,000	2,700	lube, grease	direct	Metal fillings are removed by a centrifuge prior to burning. Of 5 boilers, 3 can burn waste oil. Primary fuel F05.
Kaneohe, HI (14)		91,900	JP-5, lube	direct	Waste oil containing 10% contaminated JP-5 blended with NSFO. Lube oil treated at reclamation plant.
Keflavik, Iceland (30)		10,000	lube	direct	Waste oil/fuel oil ratio 1:10. Contaminated JP-4 burned straight; problems occur when JP-4 excessively contaminated.
Mayport, FL (6)	650,000	1,360,000	JP-4, F0 bilge, DFM, lube	in-line, direct	Direct burning of waste oil preblended with F05 (light). Packaged boilers hard to clean. Investing in a centrifuging system to control contaminants.
Miramar, CA (11)		1,382,900	bilge, JP-5, FOR	direct	Problems - fireside deposits, plugged nozzle/strainers. Routine maintenance slightly increased.
Newport, RI (4)		18,700	JP-5, DFM DF, lube	direct	Gravitation reclamation system used. Waste oil chemically tested before blending with NSFO.
Norfolk, VA (5)	4,192,000	2,690,000	FOR, JP-5, lube, F0, hydraulic	direct,	Prior to burning, waste oil & reclaimed oil analyzed for special requirements and burned as regular fuel. Some blending with NSFO. FOR from Craney Island. FY81, 2 million gallons FOR.
Oceans, VA (5)		948,000	FOR	direct	An increased burn rate of regular fuel is required to offset lower Btu value of FOR. Purchase FOR from Craney Island. Prices as of Oct 1: FOR 90¢/gal, F06 91¢/gal. 1981 952,000 gallons FOR.
Pearl Harbor, HI (14)		1,367,000	FOR	direct	Reclamation plant treats and returns FOR and downgraded DFM for burning. FY81, 32,275 barrels of FOR.
Puget Sound, WA (13)		3,400	lube, gasoline	direct	Blended with F06.
Quantico, VA (5)		4,800	JP-4, lube	direct	Blended contaminated JP-4 with F0. Burning at irregular intervals.
Rota, Spain (13)	115,000	201,000	F0, lube	in-line	Fuel loading pier is equipped with drains and holding tank for collecting spillage. Gravity separator used. Over 4 million gal/yr oily waste at 5% waste oil.
Washington, DC (21)		2,200	lube	in-line	Separation system removes excessive contaminants. Waste oil feed line tapped into fuel oil feed line with a 1:10 ratio.

continued

Table 5. Continued

Location ^a	Waste Oil Burned			Blending Method	Comments ^b
	Quantity (gal)		Type		
	FY80	FY82			
Whidbey Island, WA (13)	60,000	22,500	JP-5, FO, lube solvents	burned straight (at 100%)	One of 3 boilers modified for burning waste oil. Waste oil burned 3 months of the year at 7,500 gal/mo. Preheat boiler with natural gas. Waste oil is burned in a boiler specifically for the purpose.
Yokosuka, Japan (40)	2,000	12,000	lube, transformer oil (no PCB)	direct	

^aFigures in parentheses indicate the Naval Districts in which the locations are situated.^bFor more detail, see corresponding narrative paragraphs in text.

Table 6. Summary of Energy Usage and Waste Oil Generation and Usage by Naval District^a

Naval District ^b	Energy Usage ^c				Waste Oil Distribution ^d			Locations for Burning Waste Oil	
	All Types of Energy (MBtu)	All Types of Fuel (MBtu)	Fuel Oil (MBtu)	Ratios (%)		Generated (MBtu)	Ratios (%)		
				All Fuel/ All Energy	Fuel Oil/ All Fuel		Burned/ Generated		Generated/ Fuel Oil Used
4 (20)	16,935,096	10,158,689	7,019,698	60.0	69.1	68,033	4	1.0	Brunswick, ME Newport, RI
5 (13)	28,591,140	13,852,140	12,159,643	48.5	87.8	231,031	214 ^e	1.9	Norfolk, VA Oceana, VA Quantico, VA
6 (18)	24,201,230	10,055,901	2,743,802	41.6	27.3	334,850	65	12	Mayport, FL
8 (3)	501,614	107,504	18,601	21.4	17.3	434	0	2.3	--
9 (5)	6,689,021	3,282,321	707,645	49.1	21.6	1,975	34	0.3	Crane, IN Indianapolis, IN
11 (33)	35,087,772	18,034,168	1,812,526	51.4	10.1	1,168,577	24	58	Camp Pendleton, CA China Lake, CA El Centro, CA El Toro, CA Fallon, NV Hiram, CA
13 (12)	9,066,548	4,345,173	3,451,896	47.9	79.4	114,141	25	3.3	Adak, AK Bangor, WA Puget Sound, WA Whidbey Island, WA
14 (8)	5,479,487	737,070	702,737	13.5	95.3	567,748	70	81	Barking Sands, HI Honolulu, HI Kaneohe, HI Pearl Harbor, HI
21 (6)	10,450,704	5,366,682	4,965,946	51.4	92.5	6,254	5	0.1	Washington, DC
30 (12)	5,399,471	3,676,140	3,672,538	68.1	99.9	18,836	88	0.5	Gauntanamo, Cuba
31 (11)	2,622,060	1,357,344	1,348,785	51.8	99.4	29,664	92	2.2	Rota, Spain
40 (12)	13,421,944	5,397,720	5,394,261	40.2	99.9	66,242	35	1.2	Camp S. D. Butler, Japan Guam Yokosuka, Japan
Total (153)	158,446,087	76,371,315	43,998,078	48.2	57.6	2,607,785	57	5.9	

^aData for only the surveyed locations where fuel oil was consumed as indicated in Reference 4; totals are not Navywide totals.

^bFigure in parentheses indicates the number of locations surveyed in the Naval district.

^cFor FY80, based on Reference 4.

^dFor FY82, based on MCEL's waste oil generation/combustion experience survey; responses from 94 of the 153 locations surveyed. (One gallon waste oil = 0.1257 MBtu.)

^eSome shore facilities burn reclaimed oil received from the nearby reclamation facility; e.g., Craney Island, VA; Mayport, FL; North Island or Point Loma, San Diego, CA.

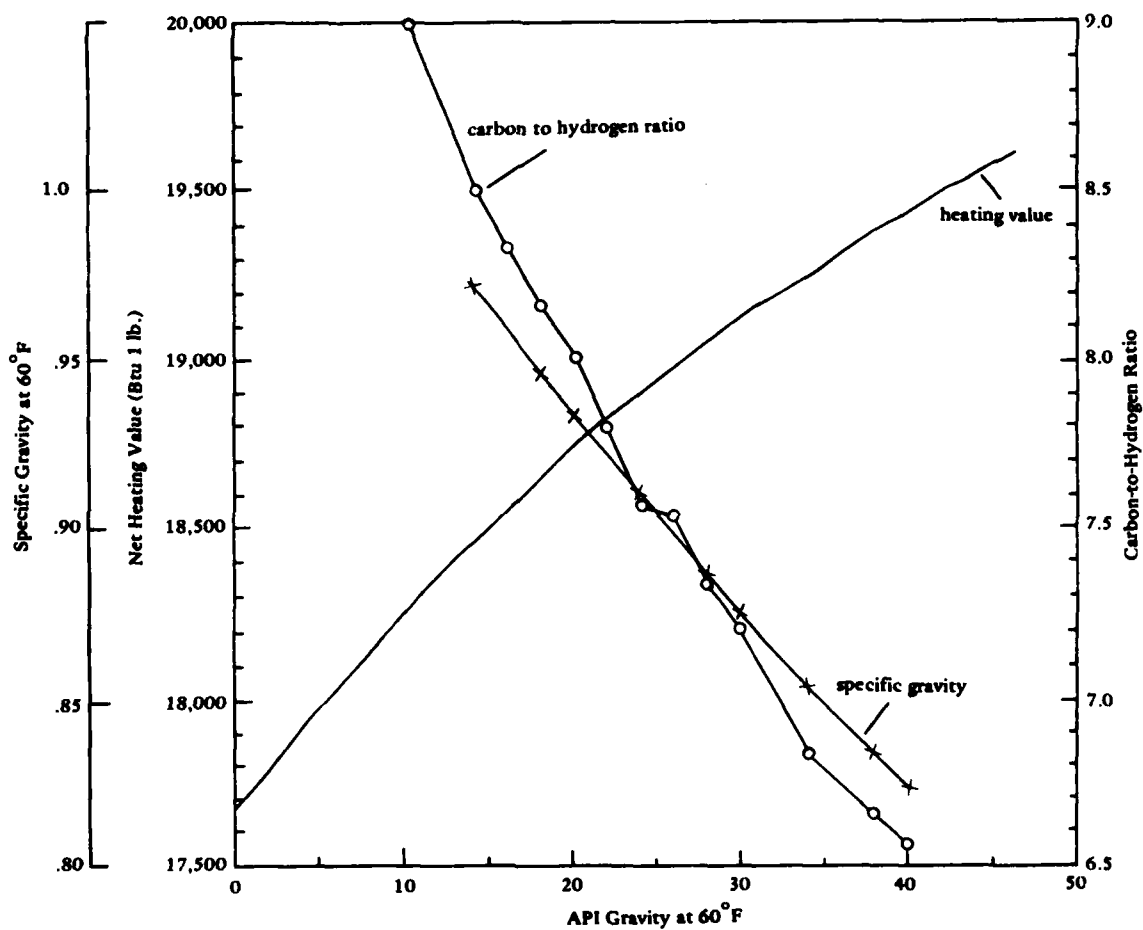


Figure 1. Relationships between heating value, carbon-to-hydrogen ratio, specific gravity and API gravity.

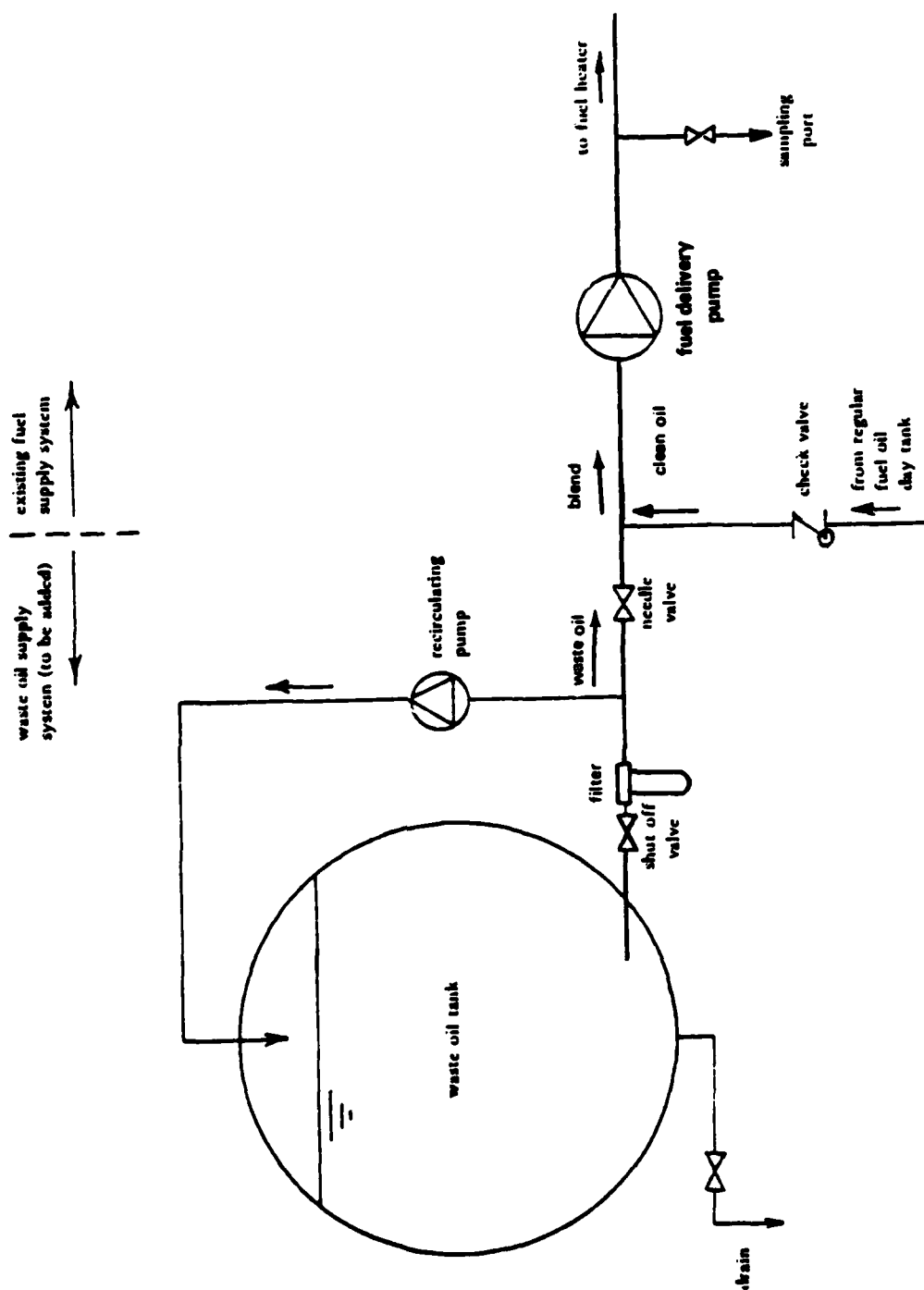


Figure 2. A scheme for in-line blending of waste oil with regular fuel oil.

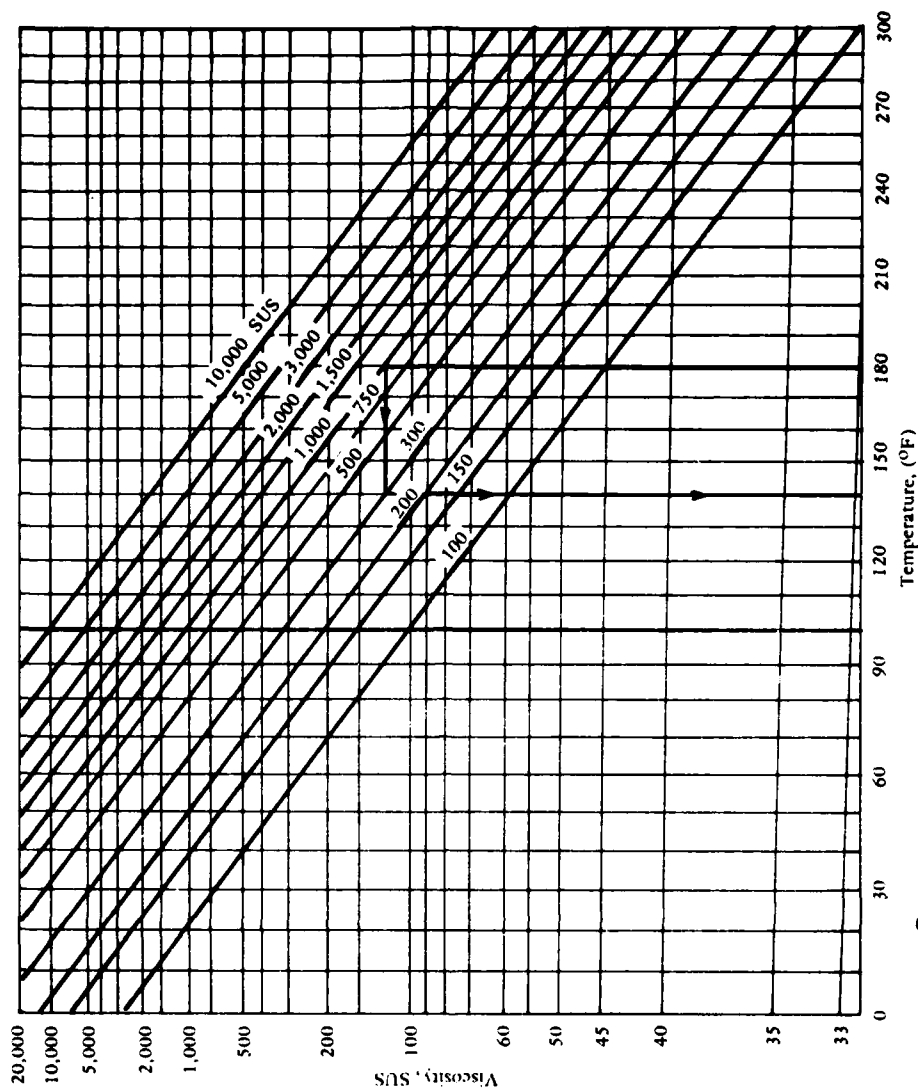
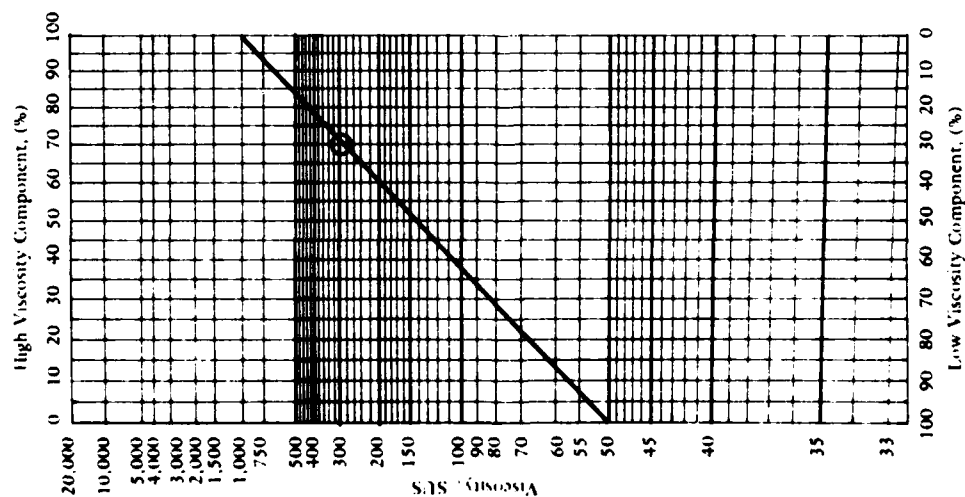


Figure 3. Charts for determination of firing temperatures for blending fuels.

APPENDIX A

OIL PRODUCTS NOT TO BE USED FOR BOILER FIRING

<u>Product Type A (Gasoline and Solvents)</u>	<u>Specification</u>
Acetone, Technical	O-A-51F
Amyl Acetate	TT-A-511C
Amyl Alcohol, Secondary	TT-A-516D
Benzene, (Benzol), Technical	VV-B-231C
Benzene, Nitration Grade	MIL-B-3137
Butyl Acetate, Normal	TT-B-838A
Butyl Acetate, Secondary	TT-B-840B
Butyl Alcohol, Normal	TT-B-846B
Butyl Alcohol, Secondary	TT-B-848B
Cleaning Compound, Solvent, Heavy Duty	O-C-1824
Cleaning Compound, Solvent	O-C-1889
1,1,1 - Trichloroethane, Technical Inhibited (Methyl Chloroform)	O-T-620C
Dry Cleaning Solvent	P-D-680
Ether, Petroleum, Technical Grade	O-E-751B
Ethyl Acetate, Technical	TT-E-751C
Ethylene Glycol Monobutyl Ether	TT-E-776B
Gasoline, Automotive	VV-G-76B
Gasoline, Unleaded	VV-G-109A
Gasoline, Automotive, Leaded and Unleaded	VV-G-1690A
Gasoline, Automotive, Combat	MIL-G-3056D
Gasoline, Aviation Grades	MIL-G-5572E

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OIL PRODUCTS NOT TO BE USED FOR BOILER FIRING (CONTINUED)

<u>Product Type F (Synthetic/Chemical Based Oils & Halogenated Solvents)</u>	<u>Specification</u>
Brake Fluid, Automotive	VV-B-680B
Brake Fluid, Silicone, Automotive, All-weather, Operational and Preservative	MIL-B-46167
Cutting Fluids Sulfurized Fatty & Mineral Oils	VV-C-850A
Grease, Silicone for use with Ammunition	MIL-G-14931
Grease, Molybdenum Disulfide	MIL-G-21164C
Grease, Silicone	MIL-G-46886
Grease, Lubricating, Halofluorocarbon	MIL-G-47219
Hydraulic Fluid, Arresting Gear	MIL-H-5559A
Hydraulic Fluid, Nonpetroleum Base, Aircraft	MIL-H-8446B
Hydraulic Fluid, Polar Type Automotive Brake	MIL-H-13910B
Hydraulic Fluid, Fire Resistant	MIL-H-19457B
Hydraulic Fluid, Catapult	MIL-H-22072A
Hydraulic Fluid, Rust Inhibited, Fire-resistant, Synthetic Hydrocarbon Base	MIL-H-46170
Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft	MIL-H-83282A
Hydraulic Fluid, Fire Resistant, Phosphate Ester Base, Aircraft	MIL-H-83306
Insulating Fluid, Electrical (Non-Combustible)	W-I-1219
Lubricating Oil, Instrument, Aircraft, Low Volatility	MIL-L-6085A
Lubricating Oil, Aircraft Turbine Engines, Synthetic Base	MIL-L-7808G
Lubricating Oil, Synthetic (for mechanical time fuses)	MIL-L-11734C
Lubricating Oil, Aircraft Turbine Engines, Synthetic Base	MIL-L-23699B
Lubricant, Molybdenum Disulfide in Isopropanol	MIL-L-24478
Lubricating Oil, Molybdenum Disulfide, Silicone Base, High Temperature	MIL-L-25681C

OIL PRODUCTS NOT TO BE USED FOR BOILER FIRING (CONTINUED)

<u>Product Type F (Synthetic/Chemical Based Oils & Halogenated Solvents)</u>	<u>Specification</u>
Lubricating Oil, Aircraft Turbine Engine, Ester Base	MIL-L-27502
Lubricating Oil, Instrument, Minus 65 Deg. To Plus 400 Deg. F	MIL-L-27694A
Lubricating, Fluorocarbon Telomer Dispersion (for use with ammunition)	MIL-L-60326
Lubricating Oil, Aircraft Turbine Engine, Polyphenyl Ether Base	MIL-L-87100
Silicone, Fluid, Chlorinated Phenyl Methyl Polysiloxane	MIL-S-81087B
Cleaning Compound, Solvent, Trichlorotrifluoroethane	MIL-C-81302C

APPENDIX B



AMERICAN NATIONAL
STANDARD

ANSI/ASTM D 396 - 79

Standard Specification for FUEL OILS¹

This standard is issued under the fixed designation D 396; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification (Note 1) covers grades of fuel oil intended for use in various types of fuel-oil-burning equipment under various climatic and operating conditions.

NOTE 1—For information on the significance of the terminology and test methods used in this specification, see the Appendix.

1.2 This specification is for the use of purchasing agencies in formulating specifications to be included in contracts for purchases of fuel oils and for the guidance of consumers of fuel oils in the selection of the grades most suitable for their needs.

NOTE 2—Nothing in this specification shall preclude observance of federal, state, or local regulations which may be more restrictive.

NOTE 3—The values stated in SI units are to be regarded as standard. The values stated in U.S. customary units are for information only.

2. General Requirements

2.1 The grades of fuel oil specified herein shall be homogeneous hydrocarbon oils, free from inorganic acid, and free from excessive amounts of solid or fibrous foreign matter likely to make frequent cleaning of suitable strainers necessary.

2.2 All grades containing residual components shall remain uniform in normal storage and not separate by gravity into light and heavy oil components outside the viscosity limits for the grade.

3. Detailed Requirements

3.1 The various grades of fuel oil shall conform to the limiting requirements shown in Table 1.

3.2 Modifications of limiting requirements

to meet special operating conditions agreed upon between the purchaser, the seller, and the supplier shall fall within limits specified for each grade, except as stated in supplementary footnotes for Table 1.

4. Test Methods

4.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM Methods,² except as may be required under 4.1.1.

4.1.1 *Flash Point*—Method D 93, Test for Flash Point by Pensky-Martens Closed Tester,³ except where other methods are prescribed by law for the determination of minimum flash point. For Grades No. 1 and No. 2, Method D 56, Test for Flash Point by Tag Closed Tester¹ may be used as an alternative with the same limits, provided the flash point is below 79.4°C (175°F) and the viscosity is below 5.8 cSt (45 SUS) at 38°C (100°F). This method will give slightly lower values. In cases of dispute, Method D 93 shall be used as the referee method.

4.1.2 *Pour Point*—Method D 97, Test for Pour Point of Petroleum Oils.⁴ Alternative test methods that indicate flow point properties may be used for low sulfur residual fuels by

¹ This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

Current edition approved March 30, 1979. Published October 1978. Originally published as D 396 - 34 T. Last previous edition D 396 - 78.

² For information on the precision of the ASTM methods of test for fuel oils refer to "An Evaluation of Methods for Determination of Sulfur in Fuel Oils" by A. R. Crawford, Esso Mathematics & Systems Inc. and G. V. Dyroff, Esso Research and Engineering Co., 1969. This document is available from the Publications Section, American Petroleum Institute, 2101 L St., N.W., Washington, D.C. 20037.

³ *Annual Book of ASTM Standards*, Part 23.

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TABLE 1 Detailed Requirements for Fuel Oils*

Grade of Fuel Oil	Flash Point, °C (°F)	Pour Point, °C (°F)	Water and Sediment, vol %	Carbon Residue on 10% Distillation, %	Ash, weight %	Distillation Temperatures, °C (°F)		Saybolt Viscosity, s ^u				Kinematic Viscosity, cSt ^b				Specific Gravity (40°C/100°F) (deg API)	Cup per Strip Method	Sulfur, wt %
						10 % Point	90 % Point	Universal at 38°C (100°F)		Fuel at 50°C (122°F)		At 38°C (100°F)		At 40°C (104°F)				
								Max	Min	Max	Min	Max	Min	Max	Min	Max	Max	
No. 1 A distillate oil intended for vaporizing pot-type burners and other burners requiring this grade of fuel	38 (100)	-18 ^c (0)	0.05	0.15	...	215 (420)	...	288 (550)	...	...	1.4	2.2	1.3	2.1	...	...	...
No. 2 A distillate oil for general purpose heating for use in burners not requiring No. 1 fuel oil	38 (100)	-6 ^c (20)	0.05	0.35	...	...	282 ^d (540)	338 (640)	...	...	2.0 ^e	3.6	1.9 ^e	3.4	...	...	0.5 ^h
No. 4 Preheating not usually required for handling or burning	55 (130)	-6 ^c (20)	0.50	...	0.10	...	...	...	(45)	(125)	5.8	26.4 ^f	5.5	24.0 ^f	...	...	...
No. 5 (Light) Preheating may be required depending on climate and equipment	55 (130)	...	1.00	...	0.10	...	...	>125 (260)	...	...	>26.4 (65 ^f)	>24.0 (58 ^f)	...	...	...	...	...
No. 5 (Heavy) Preheating may be required for burning and, in cold climates, may be required for handling	55 (130)	...	1.00	...	0.10	...	...	>300 (590)	...	...	>65 (194 ^f)	>58 (168 ^f)	...	...	...	...	...



D 338

TABLE 1 Continued

Grade of Fuel Oil	Flash Point, °C (°F)	Pour Point, °C (°F)	Water and Sediment, vol %	Carbon Residue on Ignition, %	Ash weight, %	Distillation Temperatures, °C (°F)		Saybolt Viscosity, s ^b		Kinematic Viscosity, cSt ^c						Specific Gravity 60/60°F (deg API)	Copper Strip Corrosion	Sulfur, %
						10% Point	90% Point	Universal at 38°C (100°F)	Furul at 50°C (122°F)	At 38°C (100°F)		At 40°C (104°F)		At 50°C (122°F)				
										Min	Max	Min	Max	Min	Max			
No. 6 Preheating required for burning and handling	Min 60 (140)	Max "	Max 2.00 ^d			Max "	Max "	Max "	Max "	Min >900 (1940)	Max (300)	Min (300)	Min >92	Max 638 ^e	Min "	Max "	Max "	

^a It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

^b In countries outside the United States other sulfur limits may apply.

^c Lower or higher pour points may be specified whenever required by conditions of storage or use. When pour point less than -18°C (0°F) is specified, the minimum viscosity for grade No. 2 shall be 17 cSt (31.5 SUS) and the minimum 90% point shall be waived.

^d Viscosity values in parentheses are for information only and not necessarily limiting.

^e The amount of water by distillation plus the sediment by extraction shall not exceed 2.00%. The amount of sediment by extraction shall not exceed 0.50%. A deduction in quantity shall be made for all water and sediment in excess of 1.0%.

^f Where low sulfur fuel oil is required, fuel oil falling in the viscosity range of a lower numbered grade down to and including No. 4 may be supplied by agreement between purchaser and supplier. The viscosity range of the initial shipment shall be identified and advance notice shall be required when changing from one viscosity range to another. This notice shall be in sufficient time to permit the user to make the necessary adjustments.

^g Where low sulfur fuel oil is required, Grade 6 fuel oil will be classified as low pour +15°C (60°F) max or high pour (no max). Low pour fuel oil should be used unless all tanks and lines are heated.

Appendix C

CONSIDERATIONS FOR BURNING WASTE OIL

1. Waste Oil Generated

Sources	Amounts (gal./yr)
Ship Wastewater Treatment	_____
Aircraft Maintenance	_____
Transportation Shop	_____
Navy Exchange Service Station	_____
Auto Hobby Shop	_____
Other Industrial Areas	_____
Total Quantity/yr	_____

2. Potential of Waste Oil Burning

$$\frac{\text{Waste oil generated/yr}}{\text{Fuel oil burned/yr}} \times 100\% = \begin{array}{l} \% \text{ of fuel oil requirements} \\ \text{met with waste oil} \end{array}$$

3. Capability for Burning Waste Oil

Oil-burning Boilers	
Number	_____
Size	_____
Type of Burner Equipment	_____
Mode of Operation	_____
Total Fuel Oil Requirement	_____
Fuel Storage	
Capacity	_____
Type of Handling Equipment	_____
Blending Required	Yes ___ No ___
Fuel Testing	
In-house	Yes ___ No ___
Out of house	Yes ___ No ___
Evaluations	

4. Analysis of Waste Oil Generated

API Gravity	_____
Water and Sediment Content	_____
Flashpoint	_____
Viscosity	_____
Sulphur Content	_____
Chlorine/Copper Wire Test	_____

continued

5. Economic Analysis for Burning Waste Oil

- a. \$ savings/yr = quantity of waste oil generated/yr x (unit price of new fuel - sale price of waste oil) \$ _____
- b. Initial investment \$ _____
- c. Recurring costs/yr figured from following: \$ _____

Function	Labor			Material Cost	Total Cost
	Hours	Rate	Cost		
Nonburnable Waste Segregation					
Waste Oil Testing					
Mixing/Blending					
Other (site specific)					
Total					

- d. net annual \$ savings* = \$ savings /yr - recurring costs/yr \$ _____
- e. Simple Payback Period (yr) =

$$\frac{\text{Initial investment for one time project}}{\text{net savings}}$$
\$ _____

*Savings should exceed cost of burning the waste oil.

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